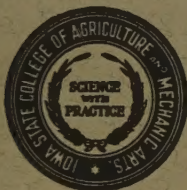


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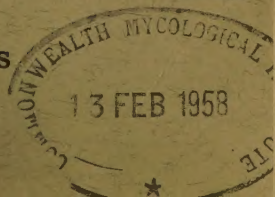
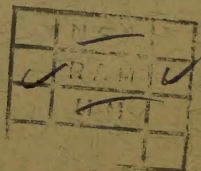
A Quarterly of Research



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ABSTRACTS OF DOCTORAL DISSERTATIONS

Accepted July 1, 1956 - June 30, 1957

These abstracts are arranged in alphabetical order by names of the authors. A footnote to each abstract carries the serial number of the candidate's thesis, the date of acceptance by the Graduate College, the academic degrees held by him, his academic position (if any) in the several departments and research institutes of Iowa State College, and the name of the chairman of his committee.

The following summaries and indices may prove helpful to those interested in tabulations and to those who wish to examine groups of abstracts of theses in the same or related fields.

1. DOCTORAL DISSERTATIONS ACCEPTED July 1, 1956 - June 30, 1957 = 122
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- a. Institutions other than Iowa State College = 100
b. Iowa State College = 22

2. INDEX TO THESES BY DEPARTMENTS. Double indexing is used in those cases where two departments are jointly responsible. The departments are arranged alphabetically. Under each department are listed the names of the authors.

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A graduate school can function only where there is adequate opportunity for research. The existence on the campus of Iowa State College of six research institutes, well integrated into the college programs, in large measure responsible for the growth of the graduate work. These institutes have frequently assumed the responsibility of providing research facilities necessary for the doctoral candidates in their respective fields. It is obvious that these institutes carry on a significant part of their research by use of workers who are in a sense apprentices in research. Under the name of each institute is given the total number of theses for which research facilities were afforded, and an alphabetical list of the authors of sponsored theses.

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SUPERCONDUCTIVITY OF LANTHANUM
AND SOME LANTHANUM ALLOYS¹Gerald Stanley Anderson²

Department of Physics

Superconductivity was observed in two crystal structures of pure lanthanum. The hexagonal close-packed form, which had the layer stacking sequence ABAC... instead of the usual ABAB..., had a transition temperature of 5.0°K. Face-centered cubic lanthanum had a transition temperature of 5.9°K.

Critical magnetic fields were determined for the face-centered cubic lanthanum, which was obtained in rather pure form. The initial slope of the critical magnetic field vs. temperature curve was found to be 550 oer/deg. This would correspond to a difference in specific heat of 0.103 cal/mole deg. for a reversible transition.

Alloys of lanthanum and yttrium were examined systematically. The same two crystal structures found in pure lanthanum were observed here. If we assume that the only variables affecting the transition temperatures for a particular structure are the volume and the mass we may obtain an expression for the transition temperature as a function of these for the hexagonal structure. The mass dependence could not be determined; however, the transition temperature seemed to depend on the volume to a power a , where $a = 25 \pm 2$.

Alloys of lanthanum and lutetium were also examined. Again it was not possible to obtain the mass dependence; however, the transition temperature seemed to depend on the volume to a power a , where $a = 9 \pm 2$.

The 95 per cent lanthanum and 5 per cent ytterbium alloy was the only one studied of these metals. Its transition temperature was 4.0°K.

¹Doctoral thesis number 1892, submitted March 12, 1957.

Chairman of Committee, Sam Legvold, Department of Physics.

²B.S., Luther College, Decorah, Iowa.

Research Assistant, Ames Laboratory of the Atomic Energy Commission.

ELECTRICAL POWER TRANSMISSION AND LOAD ANALYSIS
FOR FIELD MACHINES¹James Henry Anderson²Departments of Agricultural Engineering
and of Theoretical and Applied Mechanics

The commercial development in 1953 of the tractor-mounted generator with a 10-kw capacity opened up new possibilities in the design of agricultural field machines. The tractor-mounted generator can be used to supply electric power beyond the reaches of the power line to tools such as welders, drills, and saws. In addition, the generator affords the possibility of using an electrical coupling to drive such machines as combines, haybalers, mowers, and

¹Doctoral thesis number 1885, submitted March 4, 1957. Chairmen of Committee, Kenneth K. Barnes, Department of Agricultural Engineering and Glenn Murphy, Department of Theoretical and Applied Mechanics.

²B.S., University of Georgia, Athens.

Graduate Assistant, Agricultural Experiment Station.

other field machines. The electrical coupling is simply an alternative to the pto (power-take-off) shaft as a means of transmitting power from a tractor engine to a drawn or mounted machine.

A study was conducted to investigate the possibility of using electrical couplings to transmit power from tractors to field machines. The objectives of the study were to determine design criteria for electrical couplings for field machines and to determine design requirements for agricultural machines to be powered through electrical couplings. The problem was approached through a simultaneous machine load-analysis and performance study of the electrical system. The pto coupling was used to establish the nature and magnitude of the loads and the electrical couplings were tested under similar loads to determine the effects of the load on the electrical system.

The International Harvester Electrall system was used in the study. The Electrall system consists of a generator and motors and all wiring and controls between the two. The generator is a 12.5-kw, 208-volt, 3-phase, 60-cycle, 2-pole, 3600-rpm, 4-wire, revolving-field alternator. The motors were 208-volt, 3-phase, 60-cycle, 4-pole, 1800-rpm, low-slip, squirrel-cage induction motors. A model 60 Allis-Chalmers combine was used as the basic loading device. Electric motors were mounted on the combine so that the machine could be driven by a single-motor coupling, a multiple-motor coupling, or the standard pto coupling. The combine was instrumented so that speed, torque, and power could be obtained for the cylinder, cleaning and separating unit, and the knife and canvas drive. Recording instruments were used for recording generator voltage and motor input.

The study included both field and laboratory tests. The field tests were conducted in windrowed wheat, windrowed oats and in rowed soybeans. Stationary loading tests were conducted by feeding unthreshed wheat into the combine by means of conveyor belt. The drive losses of the combine and the performance of the electrical coupling under high overloads were studied in the laboratory.

The feed rate largely determines the power necessary to drive the cylinder. Uneven feeding of the material into the cylinder results in high peak overloads at the cylinder. The field studies indicated that many of the conditions which resulted in the cylinder stopping when the electrical couplings were used were due to uneven feeding of the material into the cylinder.

Speed regulation of the electrical couplings was poor under high peak overloads. Under suddenly applied overloads, the electrical couplings did not "carry through" satisfactorily. During overloads the generator voltage dropped substantially and the generator speed decreased because the tractor had to slow down to pick up the load. The decreased generator speed reduced the base speed of the motors. As a result of the decreased voltage and generator speed, the motors were not able to develop their normal overload capacity without a substantial speed decrease.

The response time of the governing system of the tractor was too slow when the electrical couplings were subjected to suddenly applied overloads. The electrical coupling, unlike the pto coupling, is not a rigid connection between the tractor engine and the load; consequently, more time is required for the tractor to respond to the load. This often resulted in the electrical coupling reaching a critically inefficient condition before the tractor started to restore the system to a state of equilibrium.

The performance of the multiple-motor couplings was superior to the single-motor coupling under normal load conditions. Under extremely heavy load conditions, when the generator became overloaded, no difference was noted in their performance.

The feed rate has very little influence on the power requirements of the separating and feeding units of the combine. The power required to drive these units depends largely on the power necessary to overcome friction. These loads are cyclic but the average load remains practically constant and does not impose critical load fluctuations on an electrical coupling.

Drive losses represented 25 to 30 per cent of the total power transfer in the combine used. The losses were due to friction and windage in the power train of the combine.

The results of the study point out the necessity of unique design requirements imposed on the electrical system and the machine. The design of the electrical system must be based on a study of the special load characteristics of the agricultural field machine, and the design of the field machine must be such that it will lend itself to electric drives.

On machine components which have great load fluctuations, the addition of a properly designed flywheel would permit the electrical coupling to operate at a higher level of efficiency and reduce the possibility of reaching an unstable condition during overload periods. The field machine also should be designed so that the feed flow will be even so as to reduce peak overloads. Multiple-motor couplings should be used on machines such as combines so that the drive losses could be reduced.

In the design of the electrical system, special consideration should be given to the design of the magnetic circuit for the generator. The magnetic circuit must have sufficient capacity to permit the voltage regulator to correct for the IR drop and the drop due to armature reaction. Saturation of the magnetic circuit during overloads results in reducing the effectiveness of the voltage regulator.

The tractor governor should be activated by a frequency sensing device to maintain the frequency of the generator output during overloads. Maintaining the generator speed during overloads will increase the effectiveness of the voltage regulator and maintain generator voltage during overloads thus allowing the electrical coupling to maintain the speed of the driven machine.

Direct-current electrical systems provide excellent possibilities for independent speed control of motors, high starting torques and good lugging ability under overloads and further consideration should be given to the possibility of developing a d-c coupling. The cost of a d-c system would be somewhat higher than that of an equivalent a-c system and a straight d-c system would not permit the use of standard motors found on the farmstead. Although these are serious disadvantages, the advantage of independent motor control on multiple-motor couplings and the ability to develop high starting torques and good lugging ability might outweigh the disadvantages associated with the system.

DEVELOPMENT OF A BIO-ASSAY TECHNIQUE FOR EVALUATING PHOSPHORUS AVAILABILITY IN RUMINANT FEEDS¹

Russell K. Anderson²

Department of Animal Husbandry

The purpose of this investigation was to develop an artificial rumen technique which would be suitable as an assay procedure in measuring availability of various phosphorus feeding supplements for ruminants.

A series of artificial rumen experiments were first conducted in showing a response from phosphorus additions to a phosphorus deficient basal medium using cellulose digestion as the criterion of response. Variables studied

¹Doctoral thesis number 1820, submitted July 11, 1956.

Chairman of Committee, Wise Burroughs, Department of Animal Husbandry.

²B.S., University of Minnesota, Minneapolis. M.S., Iowa State College, Ames. Instructor, Animal Nutrition.

were the number of rumen microorganisms used as inoculum, washing of the rumen microorganisms, length of the fermentation periods, types and sources of inoculum, phosphorus depleted versus nondepleted inoculum and the addition of factors to the basal medium known to be stimulatory to rumen microorganisms for the digestion of cellulose.

The technique which finally proved satisfactory consisted of measuring cellulose digestion in a series of small fermentation tubes to which graded amounts of phosphorus were added at the beginning of a 24-hour fermentation period. Phosphorus depleted inoculum was used and was obtained by incubating the microorganisms for 24 hours on a phosphorus deficient basal medium. Feather meal hydrolyzate was added to the basal medium during the depletion period in the flask and also during the assay period in the tubes. This technique produced an approximate linear relationship within limits, between the amounts of phosphorus added to the deficient medium and the amounts of cellulose digested by the rumen microorganisms.

The technique developed can be briefly summarized as follows: in a typical experiment rumen fluid was first obtained from a fistulated steer by straining rumen ingesta through four layers of number 50 cheesecloth into previously warmed thermos bottles. The strained rumen fluid was next centrifuged at a speed of about 1000 rpm for two minutes. This process sedimented partially digested feed particles and protozoa which were not completely removed by the cheesecloth. The supernatant was next centrifuged in a Sharples centrifuge at a speed of 25,000 rpm. The bacteria in the bowl of the centrifuge, with the exception of about one-fourth inch at the bottom, were collected and suspended in 1 liter of distilled water saturated with carbon dioxide gas.

The bacterial suspension was again put through the Sharples centrifuge to sediment the bacteria and remove food nutrients that might be clinging to the surface of bacterial cells. The resulting sediment was added to 1 liter of phosphorus deficient medium along with 5 grams of finely divided cellulose and 15 ml of a special 5 per cent hydrolyzate of feather meal or vitamin-free casein. The preliminary 24-hour fermentation of this suspension was carried out in a 2-liter Erlenmeyer flask which was immersed in a water bath maintained at 39°C. This phosphorus depletion fermentation was carried out under anaerobic conditions maintained by passing a constant stream of carbon dioxide gas through the suspension.

At the end of the 24-hour period half of the contents of the flask were discarded and the flask made up to 1 liter by adding phosphorus deficient medium and 5 grams of cellulose. Aliquots of 20 ml of the suspension were pipetted into 75 ml centrifuge tubes which also served as fermentation tubes. To each tube was added 0.3 ml of hydrolyzate of feather meal or casein. A standard curve was obtained by adding graded amounts of the standard phosphorus solution to the tubes. Graded levels of phosphorus feeding supplements were added to other series of tubes in determining phosphorus availability. These tubes were each fitted with a stopper with inlet and outlet glass tubing for bubbling a slow constant flow of carbon dioxide gas for purposes of agitation and maintaining anaerobic conditions. The tubes were fermented at 39°C in a water bath and at the end of the 24-hour fermentation, cellulose digestion was determined on the entire tube contents.

The availability of phosphorus in five phosphorus supplements was determined by the above procedure. These supplements were composite dicalcium phosphate, an acidulated product of phosphate, steamed bone meal, Curacao rock phosphate and colloidal clay. Dicalcium phosphate appeared to be the most available source of phosphorus of the five compounds tested in promoting cellulose digestion *in vitro* by rumen microorganisms followed by the acidulated product, steamed bone meal, Curacao rock phosphate and soft phosphate with colloidal clay. The merits of this laboratory technique in measuring phosphorus availability were discussed with respect to their transposition to feeding practice with cattle and sheep.

ELASTIC CONSTANTS OF THORIUM SINGLE CRYSTALS¹Philip Edward Armstrong²

Department of Chemistry

Values for the elastic constants c_{11} , c_{12} , and c_{44} of thorium were determined over the temperature range from 80 to 370°K, by ultrasonic sound velocity measurements. Two crystals were prepared by the strain anneal method. One crystal was cut in the shape of a circular plate about 0.7 inches in diameter by 0.06 inches thick, with the $[111]$ direction perpendicular to the crystal face. The stiffness coefficient for the $[111]$ direction was obtained from thickness mode resonance measurements. This stiffness coefficient is a function of all three elastic constants.

The other crystal was in the form of a plate 0.28 inches thick, 0.5 inches wide and 1.0 inches long. The direction perpendicular to the largest crystal face was between the $[111]$ and $[100]$ directions and close to the $(0\bar{1}1)$ plane. The cosines of this direction were determined. One longitudinal and two shear vibrational waves could be propagated in this direction. The propagation velocities were measured by the pulse-echo technique. Trial values for the elastic constants at room temperature were calculated from the direction cosines and the velocity measurements using a perturbation approximation of the equations of motion for the propagated waves. The trial values were used to calculate a stiffness coefficient for the $[111]$ direction. The coefficient measured by the resonance method was assumed to be correct. The difference between that value and the calculated value was assumed to be caused by a systematic transit time error in the pulse-echo technique. Transit time corrections were applied in proportion to the magnitudes of the velocities of propagation to make the calculated stiffness coefficient agree with the measured value. These corrections were applied to all the pulse-echo measurements and values for the elastic constants were calculated from the corrected data. Sample density and thickness over the temperatures involved were calculated from room temperature measurements and dilatometric data obtained from a polycrystalline specimen.

At 300°K, $c_{11} = 7.53 \times 10^{11}$ dyne-cm⁻², $c_{12} = 4.89 \times 10^{11}$ dyne-cm⁻² and $c_{44} = 4.78 \times 10^{11}$ dyne-cm⁻². The maximum uncertainty in these values is about one per cent. The plots of elastic constants versus temperature are roughly linear from 370 to 160°K, with definite curvatures at lower temperatures. Values for c_{11} and c_{44} increase with decreasing temperature while values for c_{12} show a slight decrease with decreasing temperature.

¹Doctoral thesis number 1905, submitted May 1, 1957.

Chairman of Committee, O. Norman Carlson, Department of Chemistry

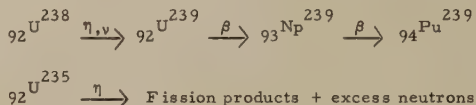
²B.S., Iowa State College, Ames. M.S., *ibid*.

Research Assistant, Institute for Atomic Research.

PURIFICATION OF PLUTONIUM BY A CHROMATOGRAPHIC METHOD¹John Augustus Ayres²

Department of Chemistry

In an atomic energy reactor or pile using uranium the two following nuclear reactions take place:



After a certain percentage of the ${}^{238}_{92}\text{U}$ has been transmuted to plutonium the uranium is removed from the pile. The plutonium and uranium are separated from each other and from the fission products and purified.

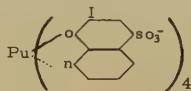
Since the radiation from the fission products is very dangerous any process for the separation and decontamination of the plutonium must be carried out by remote control with sufficient shielding to protect the operators. In these steps the fission products must be removed to such a degree that the final purification of the plutonium can be done with only moderate precautions. The degree of decontamination is expressed as the decontamination factor, which may be represented by the following ratio:

$$\frac{\text{Activity of fission products present in original}}{\text{Activity of fission products present in final}}$$

A procedure for the separation of plutonium from the uranium had been developed by Boyd and his co-workers at the University of Chicago. In their procedure the uranium from the pile was dissolved in nitric acid and the resulting solution was diluted and flowed through a column filled with an ion exchange resin. The plutonium was adsorbed on the column while most of the uranium appeared in the effluent. The remainder of the uranium was washed out with dilute sulfuric acid and the plutonium was then eluted with concentrated sodium bisulfate.

The present research was concerned with the development of an ion exchange procedure for decontaminating the plutonium. The method of approach was to use the eluate from the first or separation column as starting material and with a suitable reagent form an inner complex salt with the plutonium in this solution. The plutonium complex, having no positive charge, would not be absorbed by a cation exchange resin and would thus be separated from the fission products which were not complexed by this reagent.

From batch experiments it was found that one reagent, 7-iodo-8-hydroxy-quinoline-5-sulfonic acid (ferron), complexed plutonium to form an inner complex salt soluble in water. The formula for the resulting ion is probably



¹Doctoral thesis number 820, submitted December 2, 1946. Chairman of Committee, F.H. Spedding, Director of the Institute for Atomic Research.

²A.B., McKendree College, Lebanon, Illinois. M.S., University of Illinois, Urbana. Research Associate, Ames Laboratory of the Atomic Energy Commission.

This ion had a negative charge and was not adsorbed on the cation exchange resin at pH values between 5 and 7. At pH values below 7 most of the fission products were not complexed sufficiently to prevent adsorption by the resin. There was developed and tested out on a pilot plant scale a decontamination procedure which combined the above principle for decontamination with the separation method of Boyd. In this procedure the eluate from the first or separation column was diluted and, after the addition of carriers, was made one normal in sodium hydroxide. The precipitated hydroxides were allowed to settle and the clear supernatant was drawn off. The residue was dissolved in dilute acid and after the resulting solution was diluted and neutralized the plutonium in this solution was complexed with ferron. The complexed solution was flowed through a column filled with an ion exchange resin in the sodium form. The resin used in the experiments is sold under the trade name of Amberlite IR-1 and was obtained from Resinous Products and Chemical Corporation. The plutonium, being in the complexed state, and occurring in the solution as a negative ion, was not adsorbed on the column and appeared in the effluent. The fission products and other impurities were not complexed and were consequently adsorbed.

The complexed effluent contained the plutonium and only a small amount of fission products. It was necessary to concentrate the solution and remove the complexing agent. In order to do this and at the same time secure an additional decontamination the following procedure was employed.

The complexed effluent from the second column was acidified to a pH of 2.5 and flowed through another column (Column III) filled with ion exchange resin in the hydrogen form. The plutonium ferron complex is not stable at a low pH value. Thus the plutonium exists in solution as a positive ion and is adsorbed on the column. The ferron and some of the fission products pass on through and appear in the effluent. The column is eluted with a dilute (0.04M) solution of oxalic acid which specifically elutes that part of the zirconium and columbium which at this stage still contaminate the plutonium. In the final step the plutonium is eluted with a saturated solution of oxalic acid. The specific decontamination factors at this stage are as follows:

Cerium	4.64×10^6	Yttrium	9.0×10^5
Tellurium	$>10^7$	Strontium	$>10^7$
Zirconium	3.1×10^3	Ruthenium	$>10^7$
Over-all 1.73×10^4			

This procedure has been tested out on a pilot plant scale in a room especially designed for the process. This room, called the "hot lab", contained a large shielded hood in which the various steps of the procedure could be carried out using 1 kilogram of uranium per run. The hood was equipped with various connections enabling the operator to perform the necessary manipulations by remote control. In this room the entire procedure has been tested several times using as starting material some uranium metal from the pile at the Clinton Laboratories. The most active slugs have each contained about 5 milligrams of plutonium and about 5 curies of fission products.

The results are given for these runs showing that it is possible by using three columns to obtain an over-all decontamination factor of $10^4 - 10^5$ and a yield of over 99 per cent.

The activity remaining in the product solution at this stage is due almost entirely to the zirconium and columbium fission products. If an additional decontamination is required any procedure might be employed which would specifically remove these two contaminants. One method suggested would be the use of an additional ion exchange column resembling Column I but much smaller in size. This has been tried out on a small scale and has been found to give an additional decontamination factor of 100. Thus a four column procedure would give an over-all decontamination factor of $10^6 - 10^7$ which would meet all requirements.

Since actual pile material was used as starting material, there is little danger that any activity not specifically studied could cause difficulty. However, the procedure should be tried on a pilot plant scale using Hanford material. The laboratory at Iowa State College is not the place for these studies since any process using Hanford material even on a pilot plant scale would require a very large amount of shielding.

An additional advantage of the adsorption process over most of the other procedures is the fact that the fission products are fractionated in the procedure. Thus by only slight modifications it would be possible to obtain as by-products pure fission products, useful as tracers or as sources of radiation.

A flow sheet of the entire process is included showing the flow rates, amounts of solution, and concentrations of the solutions used. An adaptation of the procedure to a large scale is discussed and an estimate of the size and number of columns needed is given.

INFLUENCE OF HIGH SCHOOL VOCATIONAL AGRICULTURE ON FARM MECHANICS PRACTICES USED BY PARTICIPANTS IN THE VETERANS FARM TRAINING PROGRAM¹

Wilbur Perry Ball²

Department of Vocational Education

The purpose of this study was to determine the effectiveness of farm mechanics instruction in departments of vocational agriculture, as indicated by the extent to which selected farm mechanics activities had been performed on farms of high school graduates who were enrolled in the veterans farm training program.

A farm mechanics schedule which included information about various jobs, skills, decisions, and equipment was prepared and administered to veterans enrolled in 46 of 160 classes selected at random throughout Iowa. The completed schedules used in the study were divided into two groups. These groups consisted of schedules completed by veterans who had been enrolled in vocational agriculture from three to four years, during which time the equivalent of one to two semesters had been devoted to farm mechanics; and of schedules completed by veterans who had not been enrolled in vocational agriculture and therefore had not had farm mechanics instruction in high school.

Of the 56 test items included in the schedule, 29 involved manipulative jobs or skills, 15 involved managerial decisions, and 12 involved items of farm shop equipment generally found on Iowa farms. These 56 test items were selected with the assistance of staff members in Agricultural Engineering and in Agricultural Education at Iowa State College.

The sample, which was selected from approximately 1,100 veterans enrolled in the 46 classes, consisted of 357 farmers who had been graduated from high school. All of the 119 usable schedules of vocational agriculture graduates and the 238 schedules selected at random from approximately 370 nonvocational agriculture graduates were used to make up the total sample in the study. The number of cases used in each of the sampling units, or veterans classes, varied from 4 to 15 because of the variability of the population within each class. The enrollment in classes ranged from 14 to 28.

¹Doctoral thesis number 1823, submitted July 11, 1956. Chairman of Committee, John B. McClelland, Department of Vocational Education.

²B.S., Colorado State College of Agriculture and Mechanic Arts.
M.Ed., *ibid.* Instructor, Agricultural Engineering.

Chi-square analysis did not reveal very many important differences in the responses of vocational agriculture and nonvocational agriculture graduates regarding the extent to which each of 44 selected farm mechanics jobs, skills, and decisions had been performed. Differences significant at the 5 per cent level were found in the cases of one farm mechanics job and one farm mechanics decision. Of the remaining 42 farm mechanics jobs, skills, and decisions, differences in only two approached significance at the 5 per cent level.

Proportionately, a greater number of vocational agriculture graduates as compared to the number of nonvocational agriculture graduates reported the following:

1. Cleaned and adjusted spark plugs more than once by employing the services of outside persons and family members or employees.
2. Calibrated corn planters more than once by employing the services of family members or employees.

Proportionately, a greater number of nonvocational agriculture graduates as compared to the number of vocational agriculture graduates had made the following decisions:

1. Determined more than once the types and sizes of tractor units to be purchased.
2. Decided once to install tile drainage systems.

When classified on the basis of their present farming status, chi-square analysis revealed noticeable differences in the responses of vocational agriculture and nonvocational agriculture graduates with regard to the performance of 11 of the 44 selected farm mechanics jobs, skills, and decisions. Also, noticeable differences were found in 3 of the 12 selected farm shop equipment items. In 3 of the 14 items in all areas differences were significant at the 1 per cent level. In 8 items, the differences approached significance at the 5 per cent level. Proportionately, a greater number of vocational agriculture graduates classified in the high-status-in-farming group, as compared to the number of nonvocational agriculture graduates in the same category reported the following:

1. Adjusted carburetors more than once.
2. Timed distributors or magnetos more than once.
3. Repacked and adjusted wheel bearings more than once.
4. Adjusted corn picker snapping rollers more than once.
5. Mixed, poured, and cured concrete more than once.
6. Cleaned the interiors of electric motors more than once.
7. Wired one or more farm buildings more than once.
8. Determined once the types and sizes of tractor units to be purchased.
9. Made decisions once concerning custom hiring of corn pickers.
10. Made decisions more than once concerning the methods to use in harvesting crops.
11. Made decisions more than once to wire farmstead buildings other than houses.
12. Indicated the availability of tap and die sets on their farms.
13. Indicated the availability of drill presses on their farms.
14. Indicated the availability of air compressors on their farms.

When classified on a basis of the number of crop areas operated, there were noticeable differences in the responses of vocational agriculture and nonvocational agriculture graduates concerning the performance of only 3 of the 44 selected farm mechanics jobs, skills, and decisions. In 2 additional items the differences approached significance at the 5 per cent level. Of the

12 selected farm shop equipment items, only one approached significance at the 5 per cent level when classified on a basis of crop acres operated.

Proportionately, a greater number of vocational agriculture graduates in the 160-and-under-crop-acres group, as compared to the number of nonvocational agriculture graduates in the same category reported the following:

1. Determined once the types and sizes of tractor units to be purchased.
2. Made decisions more than once concerning major tractor overhaul jobs.
3. Used tap and die sets more than once.

Proportionately, a greater number of nonvocational agriculture graduates in the 161-and-over-crop-acres group, as compared to the number of vocational agricultural graduates in the same category reported the following:

1. Adjusted tractor clutches more than once.
2. Laid roofing materials more than once.
3. Cleaned interiors of electric motors more than once.

Responses of high school graduates to 56 items involving farm mechanics activities did not yield evidence to disprove the null hypothesis that there were no differences between vocational agriculture and nonvocational agriculture graduates when no classification was made of the two groups. Similarly, slight evidence was found to disprove the null hypothesis when the two groups were classified according to total crop acres operated. However, when the graduates were grouped on a basis of present status in farming, a number of significant differences were found in the high-status-in-farming group to disprove the null hypothesis. Former vocational agriculture students were found to be performing a proportionately greater number of recommended farm mechanics activities in certain areas than former nonvocational agriculture students.

VAPOR PRESSURE OF THULIUM METAL AND SOME OF ITS ALLOYS¹

Richard James Barton²

Department of Chemistry

The vapor pressures of thulium metal and the vapor pressures, crystal structures, and densities of some thulium-neodymium alloys have been investigated. The vapor pressures were measured by two modifications of the Knudsen effusion method; the weight-loss modification and the target condensation modification, the latter using a radioactive tracer technique to determine the amount of thulium deposited on the targets.

The radioactive thulium was prepared by irradiating the metal in an atomic reactor and then purifying by vacuum distillation.

Thulium was found to have a vapor pressure of 1×10^{-2} mm at 850°C and a heat of sublimation of 57.44 Kcal/mole.

Neodymium is soluble in solid thulium to the extent of about 58 per cent, and thulium is soluble in neodymium to the extent of about 25 per cent. The intervening region has many of the characteristics of the two-phase region; however, the X-ray diffraction patterns indicate it is more complex than a simple two-phase region between terminal solid solutions.

¹Doctoral thesis number 1865, submitted December 12, 1956.

Chairman of Committee, Frank H. Spedding, Department of Chemistry.

²B.S., Ohio University. Research Assistant, Institute for Atomic Energy.

The activities and the activity coefficients for the alloys were determined from the vapor pressure data. The thulium phase shows only a small positive deviation from ideality. However, in the neodymium phase the alloy at low thulium concentration shows strong negative deviation, while the two concentrations nearer to the two-phase region show marked positive deviation; the change from negative to positive deviation occurs at about 8 per cent thulium. The heats of sublimation for the alloys investigated are about the same as that of thulium except for the alloy having the lowest thulium concentration (4.63 per cent) whose heat of sublimation is 10.98 Kcal/mole higher.

Densities of the alloys were measured and they are lower than would be expected from a straight line relationship between the two pure components.

MAGNETIC PROPERTIES OF NEODYMIUM AND DYSPROSIUM SINGLE CRYSTALS¹

Donald Ray Behrendt²

Department of Physics

Single crystals of neodymium and dysprosium were grown by the Bridgman method, and their magnetic properties were measured from liquid helium temperature to room temperature.

Neodymium was found to be paramagnetic from room temperature down to 20.4°K. If χ_{11} and χ_{\perp} are respectively the molar susceptibilities parallel and perpendicular to the c_0 axis of the hexagonal structure, the experimental data for neodymium show that above 145°K $\chi_{11} = \frac{1.71}{T + 17}$ and $\chi_{\perp} = \frac{1.73}{T + 11}$, and below

145°K $\chi_{11} = \frac{1.52}{T}$ and $\chi_{\perp} = \frac{1.53}{T - 5}$. At 4.2°K neodymium appears to be antiferromagnetic, exhibiting a six-fold anisotropy in the basal plane in addition to an anisotropy of the type shown in the paramagnetic range.

The magnetic moment of dysprosium was measured with the magnetic field along three crystalline directions, these directions being a $\langle 11\bar{2}0 \rangle$, a $\langle 10\bar{1}0 \rangle$ and a $\langle 0001 \rangle$ direction. A $\langle 11\bar{2}0 \rangle$ direction is parallel to a line which passes through the centers of atoms which are nearest neighbors in the basal plane, and a $\langle 10\bar{1}0 \rangle$ direction, which is also in the basal plane, makes an angle of $\pi/6$ with a $\langle 11\bar{2}0 \rangle$ direction, while a $\langle 0001 \rangle$ is parallel to the c_0 axis.

Dysprosium was found to be paramagnetic above 178.5°K and antiferromagnetic from 85°K to 178.5°K. Below 85°K it is ferromagnetic. Above 178.5°K, the experimental susceptibilities, as defined above, are $\chi_{11} = \frac{14.14}{T - 121}$ and $\chi_{\perp} = \frac{14.16}{T - 169}$. The saturation magnetic moment determined from the ferromagnetic data for dysprosium is 350.5 c.g.s. units per gram, which corresponds to an effective magnetic moment per atom of 10.84 Bohr magnetons. The effective magnetic moment per atom determined from the paramagnetic data is 10.64 Bohr magnetons, which agrees well with the theoretical value of 10.63 Bohr magnetons for $J = 15/2$.

Below about 110°K, dysprosium exhibits a six-fold magnetic anisotropy, which increases with decreasing temperature. The value of this anisotropy at absolute zero is 3,000 oe, and as a result of the six-fold anisotropy, a

¹Doctoral thesis number 1869, submitted December 13, 1956.

Chairman of Committee, Sam Letvold, Department of Chemistry.

²B.E.S., Fenn College, Cleveland, Ohio.

Research Assistant, Ames Laboratory of the Atomic Energy Commission.

1120 direction is an easy direction of magnetization, while the c_0 axis is a hard direction of magnetization, throughout the temperature range which was investigated. The anisotropy constant associated with the c_0 axis has a magnitude of 65,000 oe at absolute zero. The experimental temperature dependences of the two anisotropy energies agree well with Zener's theory.

An interpretation of the experimental results of dysprosium is given in terms of the molecular field theory. The structure of dysprosium is divided into two magnetic sublattices, with a strong ferromagnetic coupling assumed between the atoms of any one of these two sublattices and with a relatively weak coupling of the atoms between the two sublattices.

Although the experimental results were in good agreement with the predictions of the molecular field theory for the ferromagnetic and paramagnetic temperature ranges, it was necessary to introduce a second term in the coupling between the two sublattices, in order to obtain agreement in the antiferromagnetic temperature range. This second coupling term varies as the square of the cosine of the angle between the magnetic moments of the two sublattices, in comparison to the first coupling term which varies as the cosine of the above angle. The exact physical origin of the second coupling term is not understood, although a term of this form could possibly be attributed to the effects of magnetostriction.

CHARACTERISTICS AND PRODUCTIVE CAPACITY OF GRENADA AND RELATED SOILS IN WESTERN TENNESSEE¹

Frank Fort Bell²

Department of Agronomy

During 1954 and 1955, cotton yields, soil tests, and management practices were determined on a series of cotton tracts located in farmers' fields in Haywood and Fayette Counties in western Tennessee. The purpose of the investigation was three-fold: (a) to obtain lint cotton yields on important soil mapping units under defined levels of management inputs; (b) to develop effective methods for obtaining accurate crop yields, and information on crop and soil management for certain soil mapping units using cotton as an indicator crop; (c) to relate certain soil characteristics and management inputs to lint cotton yield.

The comparison of the different soil test values within the profiles of the selected soils indicates generally higher pH values, greater amounts of available phosphorus, exchangeable potassium, and exchangeable calcium in the surface layers than in the 6 to 12" layer in most cases.

The comparison of the soil test values among the corresponding layers of the different soil profiles indicates generally greater amounts of exchangeable calcium, exchangeable potassium, and available phosphorus in Memphis and Loring profiles than in the bottomland soils; but the pH was greater in the bottomland soils than in Memphis and Loring soils, probably because of a higher percentage base saturation. Generally higher levels of exchangeable calcium, exchangeable potassium, and available phosphorus were found in Memphis and Loring soils than in Grenada soils. Very small differences in the soil test values between the Memphis and Loring profiles were found.

Fertilization rate comparisons among soils suggest that farmers recognize some chemical and physical differences among soils and apply fertilizer

¹Doctoral thesis number 1860, submitted December 8, 1956.

²Chairman of Committee, F.F. Riecken, Department of Agronomy.

³B.S.A., University of Tennessee.

accordingly, but in many cases they do not recognize certain chemical deficiencies (notably soil reaction) in soils. They also do not recognize certain chemical differences among soils, notably available phosphorus levels.

The available water supplying capacity of the selected soils appears to be different among soils and is probably the principal factor causing yield differences. The probable reasons for the differences in available water supplying capacity among soils are: (a) position of the soil on the landscape, (b) its infiltration capacity, (c) its available water holding capacity per foot, (d) the effective rooting depth of plants, (e) its evaporation losses, and (f) water table influences.

Mean yields of lint cotton from six soils were compared before dividing tracts into management classes. Criteria for dividing tracts into management classes were formulated, and yields were also compared after dividing them into management classes.

From the analysis of variance of the means, there appeared to be no management by soil type interaction in either 1954 or 1955 yield data. However, the differences among soils and among managements are both highly significant in 1954 and 1955.

The 1954 and 1955 yields results were compared before management classification. In 1954, Falaya yields were significantly greater than yields from each of the other soils, but the yields on Loring, Memphis, and Grenada were not significantly different. There was no significant difference between the 1955 yields on Ina and Falaya soils, but yields on these two soils were significantly greater than yields on each of the other soils. There was no significant difference between yields on Hymon, Loring, and Memphis soils, but yields on these soils were significantly greater than yields on Grenada soils.

The 1954 and 1955 yields were compared after management classification. The 1954 yields from Falaya at both A and B management were significantly higher than yields on any other soil studied at either A or B management. There was no significant yield difference between yields from Memphis A management, Loring A management, Loring B management, Grenada A management, or Memphis B management. However, yields from Memphis with A management were significantly greater than Grenada B management.

The 1955 yields from Ina soils with A management were significantly greater than yields on any other soils at either A or B management. But there were no significant differences in 1955 yields among Falaya A management, Hymon A management, Loring A management, or Memphis A management. Yields in 1955 from Falaya and Ina soils with B management were significantly greater than yields from Memphis B management or Grenada B management.

The cotton yields obtained in 1955 from all soils were significantly greater at A level of management than yields at B level management. However, management had little or no effect on yields on Memphis, Loring, and Grenada soils in 1954. On Falaya soils, yields in 1954 were significantly greater under A than under B management. In 1954, moisture was probably the limiting factor on cotton yield on Memphis, Loring, and Grenada soils, but was not limiting on Falaya soils.

The 1954 and 1955 growing seasons were markedly different, both in amount and distribution of rainfall as well as in mean temperatures during the growing season. These differences were reflected in cotton growth and yield of cotton to a markedly different degree among various soil mapping units and at different management levels for the same soil. The 1955 cotton yields on Loring and Memphis soils at A management were significantly greater than the 1954 cotton yields at A level of management. At B level of management the 1955 yields on Memphis, Loring, and Grenada soils were significantly greater than 1954 yields, but the mean differences between years were about one-half as great at B management level as they were at A level of management. No significant difference between the 1954 and 1955 mean yields at either level of management on Falaya was found. The yield differ-

ences between the 1954 and 1955 season on Memphis and Loring soils were higher at A than at B management level, indicating that at a higher level of management inputs the cotton plants were able to take fuller advantage of the more favorable season than at lower levels of management inputs on these soils.

The physical properties, and their effect on water and possibly air and certain fertility relations, appear to be more important in producing yield differences among soils than do the absolute amounts of exchangeable calcium, exchangeable potassium, available phosphorus, and the per cent of organic matter. The presumed more favorable water relations in the Falaya soil than that in Memphis or Loring soils suggest that root extension, activity, and ramification increased the uptake of available nutrients and water, even though the absolute amounts per unit weight of soil were less than in Memphis or Loring soils. Furthermore, the presumed more favorable water relations in the bottomland soils appears to enhance their nitrogen supplying power because of the more rapid rate of mineralization of the organic matter, even though the absolute amounts of organic matter among soils is not significantly different.

The more favorable physical properties and their consequent effect on water, air, and fertility relations, as well as the generally higher absolute level of exchangeable potassium and exchangeable calcium, may account for the difference in yields between Memphis and Grenada soils or between Loring and Grenada soils.

On three-fourths of all the tracts selected, cotton was grown continuously, and the more productive soils were cropped preferentially to cotton because of the higher return per acre from cotton than other crops grown in the region. Farmers also report that they are able to maintain and in many cases increase cotton yields under continuous culture with adequate fertilization.

FIRM-HOUSEHOLD INTERDEPENDENCE AND OTHER FACTORS
IN RELATION TO USE OF CREDIT BY FARM FAMILIES
IN GREENE COUNTY, IOWA¹

Gordon Ellsworth Bivens²

Department of Economics and Sociology

The specific objectives of this study were:

1. To determine the purpose for which farm families in the given population were using production, consumption, and real estate mortgage credit and the sources of such credit.
2. To investigate attitudes toward use of credit.
3. To analyze the relationship of selected factors to the use of credit.
4. To investigate firm-household interrelationships with particular reference to the use of funds.

¹Doctoral thesis number 1929, submitted June 6, 1957. Chairman of Committee, Earl O. Heady, Department of Economics and Sociology.

²B.S., Iowa State College, Ames. M.S., *ibid.*
Associate, Agricultural Experiment Station.

The data reported are from a survey conducted in the spring of 1956 in Greene County, Iowa, as part of Iowa Agricultural Experiment Project 1288, subproject I (now renumbered Project 1349) entitled "Factors Related to Use of Credit by Farm Families." One hundred seven schedules were obtained.

The purposes for which production credit had been or was being used and the sources of such credit were investigated. New machinery and equipment was the most common purpose for which credit was used. Feed, oil and gas, seed, and machinery and equipment repair were the next most common uses of production credit in that order. Renters and owners borrowed for similar purposes and obtained credit from similar sources. Banks were the most common source of production credit for all purposes.

The purposes for which consumer credit had been or was being used and the sources of such credit were investigated. Automobile purchase was the most common purpose for which consumer credit had been used. Banks were the most common source of consumer credit except when credit was used for television sets, furniture, washing machines, refrigerators, or kitchen ranges. In these exceptions, installment contracts from dealers were the most common source of credit.

The purposes for which real estate mortgage credit was used and the sources from which it was obtained were investigated. The two most common uses of real estate mortgage credit were to purchase the farm on which the family lived or to purchase additional land. The third most common use of real estate mortgage credit was to refinance a loan which had come due. Insurance companies and other private lending agencies were the most common sources of mortgage credit for these three purposes. Real estate mortgage credit has been used in relatively few cases to consolidate several short term debts; however, when credit was used to consolidate short term debts, banks were the most common source of credit.

Certain attitudes of these farm families toward debt were analyzed. In a tentative way, these respondents (1) exhibited an awareness that borrowed funds can serve to further financial progress and/or to achieve greater family living satisfactions, (2) indicated a reluctance to assume debt, but (3) indicated somewhat greater willingness to use credit for purchase of real estate and/or farm production purposes than for consumption purposes.

Selected factors were examined in relation to the extent to which credit was used. The relationship between age and willingness to assume debt was found to be significant. The younger farm operators were more willing to assume debt than older farm operators. However, the relationship between age and the extent to which credit was used was not significant.

The relationship between tenure status and the extent of credit use was significant; renters made more extensive use of credit than owners.

Socio-economic status, used as an indicant of the relative economic position of the families in lieu of income data, was found to bear a significant relationship to the use of credit. The higher the economic status, the greater the extent to which credit was used. Coinciding with this phenomenon was a significant positive relationship between socio-economic status and willingness to assume debt.

Knowledge of sources of credit, costs of credit, and the potentialities of credit as a productive resource was found not to be significantly related to the extent of credit use.

The relationship between educational level and the extent of credit use was found to be significant; the group which had finished high school made more extensive use of credit than the group with less than 12 years of formal education.

A particular aspect of firm-household interrelationships was examined. Since the family is the decision-making unit in the farm setting, conflict which exists within the family is a significant phenomenon affecting the use of resources. To examine differences between spouses, the responses of husbands and wives (responses of spouses were given independently) as to

their choice with respect to the use of funds for alternative purposes were analyzed by means of a paired difference technique. The differences in the ways in which a husband and wife would allocate funds became the observations; if no difference existed the observation was zero. Three major Decision Categories were aggregated:

Decision Category I: Situations involving a choice between the use of funds for investment in land or for consumption items.

Decision Category II. Situations involving a choice between use of funds for land or for farm production items other than land.

Decision Category III: Situations involving a choice between a production expenditure and a consumption expenditure.

Differences between age groups with respect to the degree of conflict between spouses about the use of funds were not significant. This would indicate that for any given type of decision, the degree of disagreement between spouses with regard to the use of funds for alternative uses is similar regardless of age.

Differences with respect to the type of decision involved were significant. This would indicate that the extent of disagreement between spouses with regard to the use of funds differs according to the type of decision involved.

Decisions which involved choices between the use of funds for investment in land vs. farm production expenditures gave rise to disagreement between spouses in more families than any other type of decision. Decisions which involved farm production expenditures vs. consumption expenditures resulted in the fewest cases of disagreement between spouses. Decisions which involved the use of funds for land vs. consumption expenditures were intermediate with respect to the number of families in which there was disagreement between spouses about the allocation of funds.

The relative consistency with which different types of decisions are made was investigated. The difference between sexes with respect to the degree of consistency of choice was nonsignificant. However, the extent to which differences in the degree of consistency of choice were associated with the type of decision was significant. Men and women followed the same pattern with respect to consistency. Both sexes were most consistent with respect to situations which involved a choice between the use of funds for production expenditure vs. consumption expenditure, and least consistent in situations which involved a choice between the use of funds for investment in land vs. consumption items. Both sexes were intermediate with respect to consistency in situations which involved a choice between the use of funds for investment in land vs. farm production expenditures.

THE NATURE OF DAMAGE TO FIELD CORN BY THE CORN EARWORM,
HELIOTHIS ZEA (BODDIE), AND THE FALL ARMYWORM,
LAPHYGMA FRUGIPERDA (A. AND S.)¹

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Department of Zoology and Entomology

The lack of published data on the location and amount of damage caused by larvae of the corn earworm, *Heliothis zea* (Boddie), and the fall armyworm, *Laphygma frugiperda* (A. and S.), when occurring together on ears of field corn, indicated the desirability of a more thorough study. This is especially important since damage caused by one species, once it has occurred, cannot be definitely distinguished from that of the other. Recent surveys of field losses caused by the corn earworm in Indiana and Illinois point up the need for rapid, accurate methods of estimating loss caused by the corn earworm.

Studies on the location of larvae and resulting damage to the ear and on methods of estimating percentage weight loss were conducted at Tifton, Georgia, where both species commonly occur in mixed populations, particularly on late season corn.

Location of Larvae and Damage

A date-of-planting experiment was conducted in 1956 using Dixie 18, the hybrid most widely grown in the South. Seven successive plantings at approximately two-week intervals were made beginning on March 20 and ending on June 18. Plots were randomized in four replicates. Important factors other than worms in the ears affecting the plantings were weather, seed source, attack by the lesser cornstalk borer, *Elasmopalpus lignosellus*, and fall armyworm feeding in whorls. The four earliest plantings developed more or less normally. Dry weather caused poor germination in the May 16 planting, and severe wilting in the June 1 planting at the midwhorl stage. Likewise drought caused the ears of the May 16 planting to be poorly filled at the tips. The last three plantings were made with seed from a different source which produced many plants with sterile tassels. The earlier of the three plantings set seed normally. Damage to young plants by the lesser cornstalk borer became increasingly severe on later plantings causing poor stands, variable in maturity, in the last two plantings. Fall armyworm infestations in the whorls of the last planting caused considerable "ragging" of the leaves. The location on the ear (tip, side, butt, shank and husks) and size of larvae (small, medium and large) were determined for approximately 400 top ears of each planting date at the roasting ear stage, for approximately 40 ears two weeks later, and approximately 40 ears again two weeks later.

At the roasting ear stage, the average number of all larvae observed per ear, and the percentage of the total composed of corn earworms were: March 20, 0.69 (100); March 29, 0.40 (100); April 16, 2.26 (100); April 30, 2.02 (99.8); May 16, 2.16 (79.5); June 1, 1.89 (44.7); and June 18, 2.33 (39.2). The number of corn earworm and fall armyworm larvae per ear decreased at the two- and four-week dissections. The number of corn earworm larvae decreased rapidly and no small larvae were recorded at the time of the four-week dissection. Fall armyworm feeding thus occurred over a longer period of time on ears than did corn earworm feeding. As the number of fall army-

¹Doctoral thesis number 1861, submitted December 11, 1956. Chairman of Committee, Tom A. Brindley, Department of Zoology and Entomology.

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worm larvae per ear increased beginning with the April 30 planting, the number of corn earworm larvae decreased. At the same time moth populations of both species were high as shown by light trap collections. The majority of corn earworm larvae of all sizes were found in the ear tips. Small corn earworm larvae were distributed over the ear more than larger larvae. Larvae of all sizes were more widely distributed among ear locations after the appearance of fall armyworm larvae. The majority of fall armyworm larvae of all sizes were found in the husks. They were distributed more over the ear than were corn earworm larvae, but from 25 to 35 per cent were in the ear tips.

Medium and large larvae feeding in the tip, side or butt were considered separately as the "damaging population" in contrast to the total population. The distribution of the damaging population differed greatly from that of the total population, but corresponded closely with the distribution of damaged kernels at harvest time. At the roasting ear stage, 99.7 per cent of the larger corn earworm larvae were in the tips of ears of the first four plantings (before the appearance of fall armyworms), and 95.2 per cent were in the tips on the last three dates (when fall armyworms were present). Over the last three dates 76.4 per cent of the larger fall armyworms were in the ear tips. At dissections made two and four weeks following the roasting ear stage, corn earworm larvae tended to be more scattered over the ear and fall armyworm larvae more concentrated in the tips. In this experiment, the major portion of the damaging population of both species occurred in the ear tips. Both species fed on kernels at the side and butt, but larvae of the fall armyworm were observed to do so more readily than corn earworm larvae.

Methods of Estimating Per Cent Weight Loss

Ten southern hybrids consisting of seven experimental hybrids, Coker 911, Georgia 103, and Dixie 18 were selected to evaluate per cent weight loss because of their differing ear and injury characteristics. Each entry was planted in 40-plant plots and replicated four times. Significant differences among entries were found for the following measurements: husk tightness; husk extension; number of second ears; yield of top and second ears separately, but not combined; ear length; number of rows per ear; ear weight; kernel weight; and extent of damage in terms of kernels, depth of penetration in inches, and shelled weight. Second ears sustained less actual damage but a higher percentage weight loss than top ears. This is attributed to the fact that they have longer, tighter husks and smaller ear size.

Three indices of percentage weight loss were calculated for top ears of each hybrid and their correlations with actual percentage weight loss compared. The indices and their correlations with actual percentage weight loss were: (1) damaged kernels divided by total kernels (DK/TK) from .93 to .99; (2) length of worm penetration on the ear divided by length of ear (DP/L) from .69 to .83; and (3) length of worm penetration on the ear divided by length of ear times number of rows of kernels (DP/L.R), .71 to .85. All of these indices were expressed as percentages. Regression coefficients for top ears pooled over the ten hybrids and passing through the origin were .8646, .2859, and 3.814 respectively. For second ears using the index DP/L, regression coefficients did not vary consistently from those for top ears and thus were considered to be essentially the same for both.

Regression equations determined from the ten hybrids were applied to 40 samples drawn in a restricted random manner from a uniformity block of Dixie 18. Samples contained 10, 15, 20, or 25 consecutive ears, there being ten samples of each size. Based on confidence intervals, standard deviations, coefficients of variation, and analyses of variation, it was concluded that (1) the regression using DP/L, estimates actual percentage weight loss as well as that using TK/DK except perhaps in small plots where a high degree of

accuracy is desired, (2) in estimating percentage weight loss for a large population, larger samples in one or two locations would provide as good an estimate as smaller scattered samples, and (3) that samples larger than 25 ears would be necessary to appreciably increase the accuracy of estimating a population mean.

The use of length measurements, DP/L , as an index of percentage weight loss is greatly enhanced by the ease and rapidity with which they may be obtained in the field as compared to kernel counts, DK/TK .

A regression equation based on length measurements and obtained by pooling over ten hybrids, which varied significantly for several ear characteristics, estimated closely the percentage weight loss occurring in Dixie 18, the most widely grown hybrid in the South, at the level of damage studied.

ELECTRICAL PROPERTIES OF EVAPORATED CARBON FILMS¹

M. Donald Blue²

Department of Physics

Uniform thin films of carbon in the thickness range 100 to 2300 Angstroms have been prepared by arc evaporation in vacuo. Large direct currents permitted evaporation rates of approximately 50 Angstroms per second. The properties of these films suggest that unannealed arc evaporated carbon had less long-range order and was, therefore, more truly amorphous in structure than any other form of carbon yet obtained. After the films had been heated to 1200°K, however, their properties were similar to ordinary fine particle carbon blacks, apparently as a result of increased ordering in graphite layers without ordering between layers. Electron diffraction pictures were similar to the x-ray diffraction pictures of fine particle carbon blacks. No structure was visible with an electron microscope. The electrical resistivity of unannealed films followed Ohm's law, was not photosensitive, and could be well-represented in the temperature range 77°K to 300°K by the equation $R = AT^{-b}$, where $b = 5$. When the carbon films were heated above room temperature, the resistivity and the exponent b were both decreased substantially. After the films had been annealed at 1200°K, the resistivity was reduced by a factor exceeding 800, and could be best represented, in the temperature range 77°K to 1200°K, by the equation $R = \alpha - T$. The values of the resistivity, temperature coefficient of resistivity, and thermoelectric power of the annealed films were then more nearly in agreement with the corresponding values for ordinary fine particle carbon blacks. Hall voltages were not large enough to be observed. No infrared absorption bands indicating possible bond resonances were observed. The effects of absorbed gases, thermo-mechanical effects, and structure dependent effects, are briefly considered, and some possible applications of the properties of these carbon films are discussed.

¹Doctoral thesis number 1826, submitted July 12, 1956.

Chairman of Committee, P.H. Carr, Department of Physics.

²B.S., Iowa State College, Ames. M.S., *ibid*.

Research Assistant, Ames Laboratory of the Atomic Energy Commission.

SIMILITUDE IN INVESTIGATIONS OF TILLAGE IMPLEMENTS¹Clarence William Bockhop²Departments of Agricultural Engineering
and of Theoretical and Applied Mechanics

Tillage is one of the oldest and most important branches of agriculture; however, there is much research to be done before the many soil variables that influence tillage equipment design can be adequately defined. This study investigates a possible procedure for the use of similitude in tillage investigations.

To develop the procedure, two scale models of a standard 26-inch disk were used, a 5-inch diameter disk and a 10-inch diameter disk. By utilizing the Buckingham Pi Theorem, and the theory of models, eight dimensionless quantities were determined, with the function established as follows:

$$\frac{R}{L^3 d} = f \frac{\lambda_j}{L}, \frac{V^2}{Lg}, U, \alpha, \beta, m, c$$

where L = diameter
R = resultant force
 λ_j = all other pertinent lengths
d = density of the soil (wet basis)
V = velocity
g = acceleration of gravity
U = ratio of the coefficient of friction of aluminum/soil
to steel/soil
 α = angle of inclination
 β = disk angle
m = moisture content in per cent
c = clay content in per cent

In the experiment, the 5-inch disk was considered the model; and the 10-inch disk, the prototype. By designing the experiment so that all independent dimensionless quantities on the right hand side of the equation are equal in the model and the prototype, one can expect the quantity $\frac{R}{L^3 d}$ in the model and prototype to be equal.

Equipment was constructed to facilitate the conduct of tillage experiments under laboratory conditions. Soil boxes were constructed for the various soils tested. The soil box was propelled by an electrically powered drive assembly. The soil-engaging implement being tested was held stationary with means provided for adjusting the furrow width and depth and the disk angle and angle of inclination.

The implement being tested was attached to a sensing device consisting of a frame suspended by six load rings. The external forces acting on the implement were determined by the measurement of the bending strains in the load rings through the use of SR-4 strain gages. The signal from the gages was amplified and recorded by an electric-stylus recording oscillograph. An event marker on the oscillograph made possible the determination of the relative velocity of the disk.

The recorded measurements were converted to the magnitude of the measured forces by the use of calibration constants. The forces constituted

¹Doctoral thesis number 1925, submitted June 5, 1957. Chairmen of Committee, Kenneth K. Barnes, Department of Agricultural Engineering and Glen Murphy, Department of Theoretical and Applied Mechanics.

²B.S., Iowa State College, Ames. M.S., *ibid*.

a noncoplanar, noncollinear, nonconcurrent force system with the resultants being an external force and an external moment. Through the use of a 6-channel recorder, the forces on the load rings were determined simultaneously; which permitted the determination of the location of the forces and the determination of the external moment.

Tests were conducted in four different soils; sand, Ida silty loam, Colo silty clay loam, and Luton silty clay. These provided clay contents ranging from 1.6 per cent to 51.2 per cent. Tests were run in sand at three different moisture levels; in Ida silty loam, at four different moisture levels; in Colo silty clay loam, at three different moisture levels; and in the Luton silty clay, at one moisture level.

Both the 5-inch and the 10-inch disks were operated in the same packing, at the same moisture level, and at the same value of $\pi_3 \left(\frac{V^2}{Lg} \right)$. The results

for both disks were plotted and the equations determined by linear regression. The t test at a 95 per cent level of significance indicated that a difference existed between the results of the two disks, although the differences were relatively small in soils of low clay content, and higher in soils of high clay content. While the lack of complete agreement indicated a possible inadequacy of the original variables in defining the soil properties, the results indicated that the similitude procedure can be used effectively.

The coefficient of friction for aluminum was determined by measuring the force required to pull a weighted aluminum slider over the surface of the soil. The coefficient of friction for aluminum is about 50 per cent greater than the coefficient for steel.

The use of similitude in predicting field results was demonstrated by predicting the draft force for a disk plow operating under field conditions. The effect of organic matter and the effect of the crop could not be included in the prediction, but the method of similitude was demonstrated with an indication that it could be utilized extensively in tillage research.

The following conclusions can be drawn from this research:

1. The principles of similitude can be effectively utilized in tillage investigations to determine the influence of soil and implement variables upon the resultant external forces on tillage implements.
 2. To develop a precise prediction equation for the resultant forces acting upon a disk, additional work is needed to determine the influence of all pertinent variables upon the resultant forces.
 3. The external forces imposed upon a disk can be resolved into a resultant force and couple. The resultant force can be located by at least six points of force measurement.
 4. The principles of similitude can be utilized effectively in predicting the forces on a disk used in the field. It must be realized that the accuracy will be dependent upon whether or not the effect of all field variables can be determined.
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EVALUATION OF PARTICLE-SIZE EFFECTS OF
SOLUBLE PHOSPHATE FERTILIZERS¹David Ritchey Bouldin²

Department of Agronomy

Experimental comparisons of plant response to granulated and pulverized forms of soluble phosphate fertilizers have not revealed any consistent differences. In some instances the pulverized form is better than the granular form, in others the reverse is true, and in still others the two forms appear to be of equal value. Presumably, these differences in behavior are associated with the properties of the soil to which the fertilizer is added; however, no previous investigation has been made of the causal relationships.

Available evidence in the literature indicates that fertilizer phosphorus additions do not become uniformly distributed throughout the cultivated layer of soil for periods of time at least as long as one cropping season. The concentration of fertilizer phosphorus in the soil is greatest at the source and decreases approximately linearly with increasing distance from the source. The volume of soil affected by unit quantity of fertilizer phosphorus decreases with increasing particle size. To explain the effects of fertilization on phosphorus availability under such circumstances, the hypothesis was developed that the increase in the availability of phosphorus associated with an addition of fertilizer phosphorus may be represented by the summation of the increases in availability of phosphorus in the individual volume units of soil into which the fertilizer phosphorus moves. The increase in availability may differ from one volume unit to another. Stated in mathematical terms,

$$A = \sum_{i=1}^n G_i V_i \quad (1)$$

where A is the increase in phosphorus availability associated with an application of fertilizer phosphorus,
 G_i is the availability of the fertilizer phosphorus per unit volume of soil, and
 V_i is the volume of soil containing fertilizer phosphorus with an availability G_i per unit volume.

By consideration of equation (1) in a qualitative way, A may be shown to increase, to remain constant, or to decrease as the particle size of the added fertilizer increases.

Equation (1) was evaluated in the laboratory from the distribution of fertilizer phosphorus around the particles and from the extractable fertilizer phosphorus per unit volume of soil. In comparing the numerical values obtained from the laboratory measurements with the relative availabilities found from plant-growth measurements, the assumption was made that the availability of the fertilizer phosphorus to plants was a unique, single-valued function of the concentration of fertilizer phosphorus per gram of soil and that the extractable phosphorus was proportional to the uptake of phosphorus by plants.

To obtain the necessary volume measurements, a technique was devised utilizing phosphorus-32 immobilization by microorganisms. The principle

¹Doctoral thesis number 1832, submitted July 31, 1956.

Chairman of Committee, C.A. Black, Department of Agronomy.

²B.S., Kansas State College, Manhattan. M.S., Iowa State College, Ames. Graduate Assistant, Agricultural Experiment Station.

underlying the method is that if the native inorganic phosphorus of a soil has been tagged with phosphorus-32, the microorganisms in the soil will convert some of the phosphorus-32 into organic forms. The organic phosphorus-32 can be measured. If a particle of nontagged fertilizer is added to this soil, the quantity of phosphorus-32 incorporated into the organic form will be smaller in the volume of soil affected by the phosphorus from the nontagged fertilizer than is the remainder of the soil. The content of organic phosphorus-32 thus is a function of the volume of soil influenced by nontagged phosphorus fertilizer. According to this method, the volumes of a sample of Seymour silt loam influenced per milligram of fertilizer phosphorus were 4.95, 3.90, 3.16, and 2.83 cm³ with 28 to 32, 16 to 20, 12 to 14, and 8 to 10-mesh sizes of NaH₂PO₄·H₂O fertilizer, respectively. No quantitative results were obtained with samples of Ida silt loam and Webster silty clay loam. Qualitatively, however, the volume of soil influenced by fertilizer phosphorus appeared to decrease with increasing particle size of fertilizer in both soils. In all soils the volumes of soil affected by fertilizer phosphorus were assumed to be spheres in which the concentration of fertilizer phosphorus decreased linearly from a maximum at the source of the phosphorus in the center to zero at the outer boundary of the sphere.

To find the extractable fertilizer phosphorus as a function of the quantity of fertilizer phosphorus per unit of soil, samples of soil were treated with small amounts of solution containing various concentrations of fertilizer. In this procedure homogeneous distribution of fertilizer phosphorus throughout the whole soil sample was obtained. After allowing a suitable time for reaction, water and an anion-exchange resin were used to extract the more reactive part of the fertilizer phosphorus. Phosphorus-32 equilibration was tried also, but this was found to measure the total fertilizer phosphorus. Empirical relationships were calculated between the phosphorus added and the phosphorus extracted.

The empirical equations calculated from the chemical measurements were combined with the assumed linear distribution of phosphorus around the particles, and equation (1) was converted to an integral involving volume of soil influenced by fertilizer as a parameter. The integral then was evaluated as a function of soil volume influenced by fertilizer.

With the Seymour silt loam, the estimated relative availabilities of the phosphorus obtained from laboratory measurements were approximately proportional to the observed relative availabilities found for the different particle sizes by growing plants in cultures of the various soils in the greenhouse. With the Webster silty clay loam, the estimated relative availability obtained from laboratory measurements increased as the volume of soil influenced by fertilizer decreased. Thus, if the volume of soil influenced by fertilizer decreased with increasing particle size, the laboratory results predict an increase in availability of the fertilizer phosphorus with increasing particle size. This behavior is in agreement with the plant-growth results. With the Ida silt loam, the estimated relative availability passed through a minimum at a volume of 4 cm³ of soil influenced per milligram of fertilizer phosphorus. Thus with this soil the laboratory results agree with the greenhouse results if the volume of soil influenced by the fertilizer exceeded 4 cm³ per milligram of fertilizer phosphorus and if the volume decreased with increasing particle size.

The results in general indicate that equation (1) is useful in fertilizer evaluation studies. Although many crude approximations were made in this investigation, the differences to be explained probably were great enough to justify these approximations. The usefulness of equation (1) would be much improved if more precise means of evaluating the fertilizer phosphorus distribution were available. The microbiological method described in this thesis could probably be improved with further work, but it is doubtful that the linear approximation for phosphorus distribution could be eliminated.

GROWTH, YIELD AND SITE REQUIREMENTS OF EASTERN COTTONWOOD¹Raymond Hugo Brendemuehl²

Departments of Forestry and of Agronomy

The objectives of this investigation were: (1) to obtain a numerical description, including growth and yield, of naturally-formed cottonwood stands growing on different flood-plain sites, and (2) to describe the soils supporting such cottonwood stands and determine the soil properties and growth factors most important in controlling growth and yield.

The basic measurement data used in describing the cottonwood stands were obtained from 66 temporary sample plots located in pure, even-aged stands along the Missouri River in western Iowa, and the Iowa, Cedar, Des Moines, and Mississippi Rivers in southeastern Iowa. From these data the following tables and/or graphs were derived: site index, number of trees per acre, stand basal area, board-foot yields (International 0.25-inch log rule), mean annual growth in board-feet (International 0.25-inch log rule), stand table and stand density index. These tables show how stand characteristics, site index, growth, and yield vary with site quality over the range of conditions investigated on the flood plains in Iowa. These tabulations also set an average standard which may be useful in guiding the silviculture and management of cottonwood growing on the bottomlands in Iowa.

The relationship between soil properties and the growth of cottonwood was studied on field plots and by means of pot experiments with cottonwood seedlings. The field study was limited to 36 plots covering the range of site qualities encountered in the growth and yield study. The field soils were all alluvial ranging in texture from coarse sands to clays. Measurements of the physical and chemical properties of each of the principal layers of the soils on the 36 plots included mechanical analysis, moisture equivalent, wilting percentage, capillary porosity, aeration porosity, total porosity, bulk density, pH, dilute acid-soluble phosphorus, initial nitrate nitrogen, and nitrate nitrogen production after two weeks' incubation. Cottonwood foliage collected from these same plots was analyzed for its nitrogen and phosphorus content.

Indirect measures of the moisture available for the growth of cottonwood, designated as available moisture capacity and moisture storage capacity, were correlated with height growth (measured as site index) at the .01 probability level of significance.

Soil texture was related to growth. Site index increased significantly when the depth to a soil layer containing more than 50 per cent sand increased. The silt fraction and the silt plus clay fraction of the soil were correlated significantly and in a positive manner with site index. The correlation of site index with the clay fraction, for the range of conditions investigated, was nonsignificant statistically.

The correlation of site index with aeration porosity approached significance at the .05 probability level suggesting this soil characteristic may be limiting growth of cottonwood in some instances. Site index was not significantly correlated with the bulk density or total porosity of the field soils examined. Greenhouse experiments with cottonwood seedlings, however, showed that growth decreased significantly as bulk density increased in four steps from 1.08 to 1.40 at moisture levels equal to the moisture equivalent and to saturation. Failure to obtain a significant correlation between bulk density and

¹Doctoral thesis number 1930, submitted June 7, 1957.

Chairmen of Committee, A.L. McComb, Department of Forestry and F.F. Riecken, Department of Agronomy.

²B.S., University of Minnesota, Minneapolis. M.S., Purdue University, Lafayette, Indiana. Instructor, Forestry.

cottonwood growth on field plots may be due to the confounding influence of other factors.

With cottonwood seedlings in pots, a moisture level representing the moisture equivalent was most favorable to growth on soils with a low bulk density whereas a lower moisture level was more favorable on soils with a high bulk density. Moisture levels near saturation were least favorable to the growth of cottonwood seedlings despite the fact cottonwood is a flood-plain species and is often considered adapted to growth in very wet soils.

The nitrate nitrogen production of the soil from the field plots after 2 weeks' incubation was significantly correlated at the .01 probability level with site index and with foliar nitrogen concentrations. The correlation between foliar nitrogen and site index was positive and significant at the .01 probability level. Dilute acid-soluble soil phosphorus was positively correlated with site index at the .05 level of probability. Foliar phosphorus was not significantly correlated with dilute acid-soluble soil phosphorus nor with site index. Cottonwood seedlings in a 3 x 3 x 3 factorial greenhouse experiment using an acid low nutrient level soil common to certain areas of southeastern Iowa showed a marked response to phosphorus and nitrogen fertilization. Potassium depressed seedling growth significantly when applied at the rate of 380 pounds of KCl per acre to the base soil with 50 pounds exchangeable potassium per acre. The field soils, in preliminary tests, showed more than 400 pounds of exchangeable potassium per acre, an amount not considered to be deficient but which may be in excess in light of the seedling experiment.

The results call attention to the importance of available moisture and the nitrate production capacity of the soil for satisfactory growth of cottonwood. These two factors explain about 50 per cent of the observed variation found among the field plots. Soil aeration and the nutrients, potassium and phosphorus, the former in excess concentrations and the latter in deficient amounts, may account for part of the still unexplained cottonwood growth variation found to exist on the bottomland sites in Iowa. A soil approximately neutral in reaction, of sufficient depth and of such texture so as to have adequate moisture holding qualities, and of medium fertility seems necessary for satisfactory growth of cottonwood. Cottonwood does not appear suited to reforestation of the acid, low fertility upland or bottomland soils of southeastern Iowa.

ETIOLOGY OF AND SCREENING METHODS FOR CERCOSPORA DISEASE OF ALFALFA¹

Raymond Dale Brigham²

Departments of Agronomy and of Botany and Plant Pathology

Cercospora disease of alfalfa, caused by *Cercospora medicaginis* Ellis and Everhart, is an important fungus disease of alfalfa from the central to the eastern United States. Breeding for resistance to this disease has been hampered by lack of an effective technique for selecting resistant plants. The purpose of this investigation was to develop a screening method for detecting resistant genotypes under greenhouse conditions, to compare field disease ratings with greenhouse ratings, and to study further the causal organism and its effect on the host plant.

¹Doctoral thesis number 1922, submitted June 4, 1956.

Chairmen of Committee, C.P. Wilsie, Department of Botany
and I.J. Johnson, Department of Agronomy.

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In the field, alfalfa clones, rated on a 1 to 9 scale, were ranked consistently for disease reaction under field conditions, and significant differences in disease resistance were found among clones. Alfalfa varieties were not ranked as consistently for disease reaction as clones either in the field or in the greenhouse. Forage yields of alfalfa varieties sprayed with fungicides were not significantly different from unsprayed plots.

The number of *Cercospora* spores entrapped on a silicone-coated slide was greater when moisture conditions were favorable. Typical lesions were produced in 13 days on spaced plants and seedlings inoculated under moist chambers, using mycelial suspensions and infested stems.

Greenhouse inoculations of alfalfa plants with mycelial fragments of *C. medicaginis* in .1 per cent Tween 20 solution were successful. Plants in pots were inoculated, placed in small moist chambers covered with translucent plastic sheeting, and incubated 5 days. Typical lesions appeared in 14 days at temperatures of 70° to 75°F.

Index of infection values were obtained for each plant. The foliage area was divided into five equal zones from top to bottom, and lesions were counted on the center leaflet of a randomly-selected leaf from each zone. The sum of the five figures was the index of infection.

To compare the amount of infection produced by mycelial fragments and spores, duplicate sets of plants were inoculated. More lesions were produced on alfalfa leaves by spore suspensions (mean index of infection 16.5) than by mycelial suspensions (mean index of infection 11.5).

Alfalfa cuttings and seedlings grown in soil showed more typical disease symptoms after inoculation than those grown in Vermiculite. Cuttings and seedlings eight to ten weeks old were more satisfactory for screening studies than younger plants, since enough leaves for dependable symptom expression are needed. Inoculations in dew deposition chambers showed that excessive moisture reduced amount of infection. Most lesions developed at 70° to 80°F.

Index of infection values for 30 alfalfa clones inoculated in the greenhouse were significantly correlated ($r = .38$) with field disease ratings. Relationships of index of infection values for the 30 clones and their S_1 progenies was expressed by a significant correlation coefficient of .52. Clones and progenies were ranked consistently for disease reaction, but two or more replicated tests are recommended when screening clones.

Alfalfa, red clover, sweet clover, and Ladino clover were cross-inoculated with isolates of *Cercospora* species from alfalfa, red clover, and sweet clover. The isolate from alfalfa parasitized alfalfa only, but isolates from red clover and sweet clover produced atypical lesions on hosts other than the species from which they were isolated.

As part of a long-term search for disease resistance and genetic markers in alfalfa, X-rays were applied to seeds of diploid and tetraploid alfalfas. Seeds of the alfalfa variety Vernal, irradiated at ten dosage levels from 2,500 to 640,000 roentgen units, produced seedlings which emerged normally except at the highest dosage level. No seedlings survived more than a few weeks at dosages above 80,000 roentgen units. Dosage levels of 20,000, 40,000, and 80,000 roentgen units were applied to seeds of three diploid and three tetraploid alfalfa varieties. Diploid plants were found more resistant than tetraploid plants.

Crude protein, ether extract, ash, and crude fiber were determined by chemical analyses of alfalfa leaves with 0, 1/8, 1/4, and 1/2 of their surface area infected with *C. medicaginis*. Crude protein content in healthy leaves was 33.12 per cent, compared to 20.00, 18.06, and 18.12 per cent for leaves 1/8, 1/4, and 1/2 diseased. Forty per cent less crude protein was found in leaves 1/8 diseased than in healthy leaves. A small decrease was found from 1/8 to 1/4 diseased leaves.

C. medicaginis spores were picked from sporulating areas on leaves and stems with an agar-coated needle. Sporulation and production of viable spores occurred in 6 hours when infested alfalfa stems were placed in Petri dish

moist chambers. Mean length of 231 spores in distilled water was 165 microns, and mean width was 3.95 microns.

Conidial and mycelial fragments were mounted in distilled water and .1 per cent Tween 20 solution. Germ tubes from spores and hyphae from mycelial fragments were produced in less than 6 hours at 15° to 30°C. Growth of germ tubes from spores was greater than growth of hyphae from mycelial fragments. No significant differences were found in germ tube or hyphal growth when distilled water and Tween 20 solution were used as substrates.

Infested stems of alfalfa were found to support sporulation of C. medicaginis after storage for 17 months in the laboratory, greenhouse, and outdoors.

C. medicaginis grew satisfactorily on PDA at pH 5, 7, and 9. On nonacidified PDA and other dehydrated media, newer isolates produced a trace of sporulation, but old isolates did not. New and old isolates sporulated on four fresh leaf decoction agars, with more sporulation on new isolates. Spores were produced in culture on fresh leaf decoction agars, but not in sufficient amounts for a large screening program.

Detached alfalfa leaves, on cotton moistened in distilled water and in 2 per cent sucrose solution, became infected by spores in 8 days. At 14 days, leaves were infected by both spores and mycelial suspensions, but severe chlorosis and other abnormalities prevented expression of normal symptoms. Lesions produced on leaves were atypical, and fruiting was abnormal.

The name "Cercospora disease of alfalfa" is proposed for all phases of disease on alfalfa caused by C. medicaginis.

ADJUSTMENT OF VALUE PRODUCTIVITY ESTIMATES TO CHANGES IN PRICE AND TECHNICAL RELATIONSHIPS¹

David William Brown²

Department of Economics and Sociology

Continuing estimates of the returns to resources used in agricultural production can help the various components of economic society to achieve their respective goals. Several analytical tools have been used to estimate resource returns in agriculture. One of these procedures involves the use of income functions that have been derived from farm records. However, the usefulness of estimates from these income functions is restricted in that they are oriented to specific price and physical input-output relationships.

The objective of this study was to explore the possibility of adjusting empirical income functions for changes in (1) product and resource prices and (2) the physical production associated with any selected input combination. No attempt was made to test fully the accuracy of the estimates which result from the adjusted functions. Rather, this study proposed and appraised several alternative procedures that might be used to make these adjustments within the limits of the information actually available.

The problem was approached in the following manner. First, alternative schemes for incorporating changes in prices and physical input-output relationships into the estimating equations were suggested. Then, possible ways for determining the extent to which prices and production responses had changed were considered. Finally, the adjustment procedure which seemed

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to be most appropriate under the existing restrictions in information was selected and its use illustrated with an empirical example that drew on actual farming experience in Iowa.

It was suggested that the adaptation of income functions to changes in prices and physical production responses may be achieved in any of three ways: (1) adjustment of the basic input and output data to which the original functions have been fitted, (2) adjustment of the parameters of the original estimating equations, or (3) adjustment of the original estimates of resource returns. Adjustment of the parameters of the estimating equations seemed to be the most easily applied procedure when estimates are to be made for several points on the income surface. The procedure in which the original estimates of resource returns are adjusted appeared to be useful when only one or two points on the income surface are involved. Adjustment of the original observations, although requiring more work than the other procedures, was found to be more flexible in that it allows adjustments to be made for nonproportional shifts in income surfaces. There seemed to be no reason why these adjustment procedures could not be applied to any mathematical relationship that might be used to fit the income surfaces. An example in which three kinds of functions --the exponential (Cobb-Douglas), a modified exponential, and a simple quadratic--were fitted to hypothetical data gave results which were consistent with this hypothesis.

Estimation of the direction and degree of change in prices and technical relationships for the various inputs and outputs in the function was seen to involve two subproblems: (1) selection of the most appropriate price and yield-response information and (2) selection of the most suitable indexing scheme.

It was conceived that price and yield-response information which corresponds to the geographical location, time, and kinds of inputs and outputs associated with any income function is not always available. However, study of several historical price and yield series led to the conclusion that, for many inputs and outputs, changes in prices or physical output responses may be estimated with reasonable accuracy by substituting data that does not exactly correspond to the universe of farms for which resource returns are to be estimated.

Several possible schemes for estimating price and productivity indexes were considered. Use of a weighted arithmetic mean of the price relatives of the component items (Laspeyres' index) appeared to be as suitable as any scheme for the limited weighting information that is likely to be available in practice. The weights used would be the dollar values of the inputs or outputs of which the index is composed. It was suggested that certain unweighted indexing schemes may be reported to without serious consequences when the required weighting information is not available.

Construction of the price and physical productivity indexes and the use of these indexes to adjust estimates of resource returns were illustrated with actual farming experiences in the Tama-Muscatine soil association area of east-central Iowa. Cobb-Douglas production functions were derived for the crop and livestock enterprises from survey information which had been collected from a sample of farms in this soil area for the 1954 calendar year. Indexes of the changes in prices and technical relationships that had occurred between 1954 and 1955 were constructed for every input and output aggregate in the functions. These indexes were used to adjust the coefficients of the 1954 income functions so that resource returns for 1955 could be estimated.

A rough check on the accuracy of the adjustments was made by comparing the estimated changes in gross and net incomes with parallel estimates from two other studies of Cornbelt farms. The estimates from the Tama-Muscatine functions showed both gross and net incomes to be lower in 1955 than in 1954. The two studies being used as "checks" also showed income reductions in 1955. Moreover, the estimated degrees of change (percentagewise) were nearly the same for all three studies.

These results suggested that, even though all the required background information is seldom available, reasonably accurate estimates of resource returns can be obtained from income functions that have been adjusted for changes in prices and physical production responses. The application of these adjustment procedures may, therefore, greatly magnify the capabilities of the income function as a tool of economic analysis.

AN ITERATIVE METHOD APPLIED TO WAVE GUIDE AND RESONANT CAVITY PROBLEMS¹

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Department of Electrical Engineering

The objective of this dissertation is to present an iterative method for the solution of wave guide and resonant cavity problems involving boundaries of arbitrary shape. The method is essentially an extension of Picard's method of successive approximations to apply to certain two and three-dimensional boundary-value problems. With each step of the iterative process successive approximations are obtained for both the eigenfunction and eigenvalue for the particular mode of interest, and the process is shown to be convergent.

The method is first applied to the classical Sturm-Liouville problem

$$Ly = -\lambda y, \quad a \leq x \leq b, \quad U_1 = 0$$

where $L = \frac{d^2}{dx^2} - q(x)$,

(1)

U_1 denotes the boundary condition equations and λ is the parameter of the system. Successive approximations are generated by the recursion equation

$$Ly^n = -\lambda^n y^{n-1}$$

$$U_1 = 0$$
(2)

where the superscript n is used to denote the n th approximation rather than a power. The initial function y^0 is arbitrary except that it must satisfy the boundary conditions and be normalized, and the quantity λ^n is chosen with each step such that the resultant y^n will also be normalized.

The method is shown to converge by first writing the solution of (2) in the form

$$y^n(x) = -\lambda^n \int_a^b G(x, \xi) y^{n-1}(\xi) d\xi$$
(3)

where $G(x, \xi)$ is the Green's function for the homogeneous system

$$Ly = 0$$

$$U_1 = 0$$
(4)

¹Doctoral thesis number 1835, submitted August 8, 1956, Chairman of Committee, L. W. Von Tersch, Department of Electrical Engineering.

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Then y^{n-1} and G can be expanded in terms of the eigenfunctions of (1), and the resultant series for y^n compared with that for y^{n-1} . It is found that the higher order terms of the approximate solution are reduced relative to the lowest one with each step of the process. Thus, in the limit, y^n approaches the lowest order eigenfunction contained in the expansion of y^0 , and λ^n approaches the corresponding eigenvalue. Any particular higher order mode can be obtained by beginning the iterative process with an initial y^0 function which does not contain terms of lower order than the one of interest. In order to find such an initial function, all eigenfunctions of lower order than the one of interest must first be found, and then the corresponding terms contained in any arbitrary function can be obtained and subtracted out to give an appropriate starting function.

The method is next applied to the equation

$$[\nabla^2 - q(\chi, y)] \varphi = -\lambda \varphi \quad (5)$$

where ∇^2 is the two-dimensional Laplacian operator. Two different cases of boundary conditions are considered: one where the function φ is equal to zero on the closed boundary C , and the other where the normal derivative is zero on C . This equation with $q = 0$ describes the two possible wave guide modes. The TM mode is obtained by using the first of the two boundary conditions and TE mode by using the second one. The proof of convergence is quite similar to that used for the Sturm-Liouville problem. The Green's functions encountered in the two cases can be described in terms of electrostatics. The one for the TM case may be thought of as the potential function arising from a fine line of charge at a point (ξ, η) and surrounded by a conducting boundary at C . The Green's function for the TE case does not exist for the problem as it stands because of the eigenvalue at zero. This difficulty is obviated letting q in (5) be a constant δ rather than zero and proceeding to find the Green's function for small δ . The resulting function may be thought of as the potential due to a fine line of charge at (ξ, η) , a uniform charge density within C , and a double layer of charge on C .

The method is then extended further to the vector wave equation

$$\nabla^2 \vec{A} + \lambda \vec{A} = 0 \quad (6)$$

subject to two possible boundary conditions: (1) the tangential component of \vec{A} is zero on the closed boundary surface S , and (2) the normal component of \vec{A} is zero on S . The electric and magnetic fields in a resonant cavity must satisfy (6) and the first and second boundary conditions respectively. The iterative procedure used here is essentially the same as that used in the previous cases, except for dealing with vectors rather than scalars. The vector nature of the functions being dealt with necessitates using a dyadic Green's function for this problem.

A great deal of use is made of the Green's function concept in discussing some of the generalities of the method. However, the iterative procedure described does not lend itself very well to actual numerical solution of problems because of the generally difficult task of evaluating the Green's functions encountered. Thus a modification of the method is considered in which the Green's function problem is avoided.

The basic idea of the modification can be illustrated by means of an example. In the TM mode case of the wave guide problem the recursion equation which must be solved with each step of the process is just Poisson's equation. Instead of writing the solution for φ^n , say, in terms of Green's function and φ^{n-1} , one can integrate the equation directly. In doing so one does not obtain φ^n explicitly as a function of φ^{n-1} , though, as the normal derivative of φ^n is contained within one of the integral terms on the right of the equation. However, for large n successive approximations are nearly equal. This leads one to wonder if a convergent process would be obtained if the φ^n term within the integral term were replaced with φ^{n-1} which is known.

Nothing general regarding the convergence of such a scheme is developed, but this approach is applied to a square wave guide example, and the process appears to converge for this case. The possible extension to other problems including the resonant cavity one is also considered.

ISOMERISM IN W^{181} ¹

Alfred Joseph Bureau²

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With the X-ray beam of the Iowa State College 75-Mev Synchrotron as the means of excitation, a search was initiated for nuclear isomers with half lives greater than 5 microseconds. Such an isomeric transition was observed from the excitation of a metastable level in W^{181} by a (γ, n) reaction on W^{182} . The energy and half life of the gamma ray resulting from the decay of this isomeric level were found to be 366 ± 4 kilovolts and 14.4 ± 0.3 microseconds respectively. A measurement of the K-shell conversion coefficient gave a value of $0.3 \pm .03$. These results suggest that the transition is an admixture of multipole orders, $0.28E1 + 0.72M2$. The assignment of this mixture of multipole orders agrees with the transition probability computed from Nilsson's wave functions (1) for the first excited state and the ground state of the W^{181} nucleus.

The measurement of activities with half lives of this duration requires that observations be performed between the beam bursts of a pulsed accelerator. Until recently, such attempts to measure short lived isomers have been unsuccessful because of the problems associated with the beam burst or the beam engendered background activity. Initial attempts to measure activities between the X-ray bursts of the Iowa State College Synchrotron were hindered by beam straggling, saturation of the analyzing system by scattered radiation, and a high background (neutron) activity. The elimination of these difficulties made possible the measurement of such short lived activities.

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¹Doctoral thesis number 1862, submitted December 11, 1956.

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METABOLISM OF DDT IN THE WHITE RAT¹Edward Columbus Burns²

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Mixtures of radioactive DDT (¹⁴C-labeled in the *p,p'*-positions of the benzene rings, 0.75 mC/mM) and nonradioactive DDT, 2,2-bis(*p*-chlorophenyl) 1,1,1-trichloroethane, in corn oil solutions were administered orally to male, white rats (Sprague-Dawley strain) and the metabolic products in the bile and in the intestinal and thoracic duct lymph were investigated in order to learn more about the intermediary metabolism of this insecticide in mammals. The function of the bile in the excretion of DDT also was investigated. Techniques are described for cannulation of the common bile duct, urinary bladder, thoracic duct and intestinal lymphatic of the white rat.

As much as 20 per cent of a subacute oral dose of DDT in corn oil was recovered by cannulation of the common bile duct a few hours after administration of the insecticide. The principal metabolite of DDT in the bile as determined by radiometric, colorimetric, and chromatographic methods is believed to be DDA, 2,2-bis(*p*-chlorophenyl) acetic acid, or a mixture of similar compounds. Most of the DDT metabolites from the bile were voided in the feces and very little was eliminated via the urine. When the common bile duct was ligated and excised, the kidneys appeared to play a major role in the elimination of the metabolites of DDT.

A maximum of 25 per cent of the administered radioactivity was recovered from intestinal lymph while 7 per cent was the maximum recovery from thoracic duct lymph. Fat was removed from all of the lymph samples with a Davidow³ acid-Celite column before radiometric or colorimetric analysis. No alkaline soluble material could be recovered through washing the diethyl ether extracts of intestinal and thoracic duct lymph. This indicated that DDA or other alkaline soluble materials were not present in lymph.

A prominent blue color, typical of DDT, was obtained when extracts of intestinal lymph from several rats were subjected to the Schecter *et al.*⁴ colorimetric method of analysis and the spectral transmittance curves were essentially identical to that obtained from a DDT standard. Similar colors and spectral transmittance curves were obtained from extracts of composited thoracic duct lymph of two rats, and with the exception of one sample, collected 35-47 hours after dosage, the same results were obtained with thoracic duct samples collected at intervals following administration of the DDT. A pinkish-blue color was obtained from the 35-47 hour sample and there was a marked difference in the spectral transmittance curve. This suggests the presence of DDE, 2,2-bis(*p*-chlorophenyl) 1,1-dichloroethylene, or similar metabolites in thoracic duct lymph.

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¹Doctoral thesis number 1919, submitted June 3, 1957. Chairman of Committee, Paul A. Dahm, Department of Zoology and Entomology.

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³Davidow, B. 1950. Isolation of DDT from fat. *Assoc. Off. Agric. Chem. Jour.* 33:130-132.

⁴Schecter, M.S., S.B. Soloway, R.A. Hayes, and H.L. Haller. 1945. Colorimetric determination of DDT. *Indust. and Engineer. Chem., Analyt. Ed.* 17:704-709.

SOME PROPERTIES OF THE AVIAN BRONCHITIS VIRUS¹Darwin Arthur Buthala²

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Avian bronchitis is an acute, highly infectious virus disease of chickens which annually causes considerable loss to the poultry industry through death of baby chickens, loss in weight in broiler birds, and lowered egg production in infected laying flocks. The etiologic agent of the disease has been shown to pass all grades of Berkefeld filters, to be inactivated by heat and chemical disinfectants, to grow only in the presence of the living susceptible cell, and to be cultivatable in the embryonated chicken egg.

The present investigation was initiated to determine additional properties of the avian bronchitis virus.

It was found that the allantoic fluid from 13-day-old chicken embryos, either normal or infected with the virus, appeared by agar diffusion analysis to be antigenically similar. There was a minimum of 7 precipitating antigens observed in virus-containing allantoic fluid as demonstrated by zones of precipitation in agar gel; however, no zone was noted that could be ascribed to the virus. In the main these allantoic fluid antigens were found to be heat labile and were precipitated by trichloroacetic acid. Oxidation by potassium periodate with ether did not reduce the number of precipitating materials. Treatment with ficin for one hour caused a reduction in density of the zones of precipitation without a reduction in number of zones. Treatment with trypsin for 4 hours reduced the number of precipitation zones to three faint areas. It appears that the majority of the antigenic materials in allantoic fluid are protein in nature.

In a series of studies virus-containing allantoic fluid was subjected to several chemical or physical procedures designed to remove the virus from suspension. The following observations were made: (1) the virus was partially sedimented by ultracentrifugation, (2) adjustment of the specific gravity of the suspending medium to a lower value did not influence the effectiveness of sedimentation, (3) one isolate, designated No. 33, was absorbed to Seitz asbestos filter pads; however, absorption was reduced by diluting the virus-containing fluid with tryptose phosphate broth, (4) cation and anion exchange resins were not effective in removing the virus from suspension, (5) aluminum phosphate gel suspended in phosphate buffer of various pH and molar values did not absorb the virus, (6) 50 per cent of the virus was removed from the allantoic fluid as a part of a thermodependent precipitate which formed at temperatures of 4°C or below, (7) ammonium sulfate precipitated the virus in a concentration of 30, 50, or 70 per cent of saturation, (8) increased virus yield was obtained if the fluid was allowed to precipitate for 3 hours, (9) antibody in combination with virus treated with trypsin did not release active virus, although antibody was shown to be inactivated by trypsin treatment in the absence of virus, and (10) trypsin did not inactivate the virus in a concentration of 40 mg of trypsin/ml of virus-containing fluid.

Electron micrographs of the deposit from No. 97 virus-containing allantoic fluid following a single cycle of high speed-low speed centrifugation showed the presence of 120 m μ particles intermixed with much amorphous material. Following trypsinization of this material the 120 m μ particles were still present but much of the amorphous material had been removed.

In experiments designed to unmask hemagglutinin associated with the virus

¹Doctoral thesis number 1868, submitted December 13, 1956.

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it was found that allantoic fluid from embryos infected with the virus did not cause agglutination of erythrocytes of a number of common animal species under a variety of experimental conditions.

It was found that the virus infectivity remained following lyophilization at a pressure of 8 to 10 microns of mercury. Several suspending media maintained virus titer in the lyophilized preparations without loss for a period of at least 7 days, namely: 10 per cent glucose, 20 per cent inactivated horse serum, tryptose phosphate broth or 10 per cent skim milk. A tenfold drop in titer was noted with 20 per cent inactivated bovine serum, 1.5 per cent bovine albumin, 1.0 per cent lactalbumin, 10 per cent sucrose or undiluted allantoic fluid. A hundredfold loss in titer was observed with 0.01 M phosphate buffer, 10 per cent fructose or 3 per cent gum acacia.

The density of the virus was determined in sucrose and glycerine solutions. It was found that the density was between 1.16 and 1.15 in sucrose solutions and between 1.14 and 1.13 in glycerine solutions.

Evidence obtained indicates that the virus does not grow in susceptible living cells *in vitro* under the conditions employed in the experiments. Various tissues from the chicken embryo were prepared in a variety of media and culture types. Virus was observed to be released in deembryonated egg preparations only when the intact embryonated egg had been inoculated with the virus 3.5 hours prior to deembryonation. The titer of the virus released *in vitro* was low as compared to the titer attained in the intact embryo inoculated with the same amount of virus and incubated for a similar period of time.

SEQUENCE RELATIONSHIPS OF CLARION, LESTER, AND HAYDEN SOIL CATENAS¹

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Department of Agronomy

The main soils of Iowa derived from the Late Wisconsin glacial drift have been grouped in three toposequences or catenas and three biosequences as shown in Table 1.

The members missing in this table and predicted to occur by genetic theory were found in the field and described.

The transitional Webster-Ames soil seems to be common in the area traversed, mainly adjacent to the Des Moines River in Boone and Webster Counties, and to have a relatively large areal distribution there. It appears to be different from the Dundas series tentatively established in Rice County, Minnesota. The Hayden-Ames intergrade seems to have a small areal distribution and to occur in very narrow bands which can be mapped only on four inches to the mile or greater scale.

To study the sequence relationships of the nine soil units (seven listed in Table 1 plus the two new units) samples were taken of all horizons of each one.

Particle size analysis was made; total carbon, total nitrogen, exchangeable Ca, exchangeable Mg, exchangeable K, exchangeable H, and pH were determined; clay ratios, C/N ratios, exchangeable Ca/Mg ratios, and per cent base saturation were calculated; a thin section study of the major horizons of the soils developed under trees and under transition prairie-trees was made, particularly to get information about clay translocation and accumulation as films on soil aggregate surfaces and pore walls.

¹Doctoral thesis number 1887, submitted March 8, 1957.

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Table 1. The series forming soil biosequences and toposequences of central Iowa

Toposequences	Biosequences		
	Under prairie	Transition prairie-trees	Under trees
Well drained	Clarion	Lester	Hayden
Moderately well drained	Nicollet	Le Sueur	?
Poorly drained	Webster	?	Ames

All data obtained showed important toposequence relationships among the soils developed under variable topography when the other four main soil forming factors are considered constant, and biosequence relationships among the soils developed under variable vegetation when the remaining factors of soil formation are assumed to be the same.

Oriented clay films on pore walls, channel sides, aggregate surfaces, and channel constrictions observed in the thin sections seem to be evidence of clay translocation from the upper to the lower horizons of the sola of the soils studied.

The toposequence and biosequence relationships described showed that the continuous and gradual variation of the soil properties expected from the similar continuity of variation of the environmental soil forming factors is a fact and that the genetic grouping of soils, giving emphasis to that continuous and gradual variation, is sound and very useful.

HERITABILITY OF GAIN AND GRADE IN BEEF CATTLE¹

Robert Clifton Carter²

Department of Animal Husbandry

The objectives of this experiment, conducted at the Virginia Agricultural Experiment Station, were:

1. To estimate directly the heritability of the rate of gain in beef cattle and the progress to be expected by selection.
2. To estimate indirectly the heritability of other economic traits in beef cattle.
3. To estimate the genetic and phenotypic relationships among certain production characters in beef cattle.

Young beef bulls were full fed individually for 168 days following weaning. Those with the highest and lowest rates of gain were selected and paired (one fast with one slow gaining bull) for progeny testing. A total of 18 pairs (36 bulls) were selected from the 119 on test during a five-year period. The average difference in rate of gain between the selected high and low gaining bulls was .56 lbs per day. This selection differential was twice the standard deviation of daily gain within year, breed and age groups of bulls on test.

¹Doctoral thesis number 1858, submitted December 6, 1956.

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Equal numbers of cows from sets of half-sibs in the test herd of grade Hereford cows were assigned at random to each bull of a pair. The resulting steer progeny were full fed for 200 days beginning at weaning. The heifer progeny were wintered largely on roughage and were tested by their gains on pasture their yearling summer. The average difference between the steer progenies of the high and low gaining sires was .087 lbs in daily gain on test. Between the heifer progenies the average difference was .058 lbs per day.

Heritability of daily gain was estimated by dividing the average difference between the progenies of the high and low gaining sires by the average difference between the two kinds of sires and then doubling the resulting regression. These estimates and the 95 per cent confidence interval are: for the steers .37 (.73 to .05) and for the heifers .34 (.66 to .02).

Heritability estimates for daily gain and for the other traits studied were also obtained from intraclass correlation of paternal half-sibs. For certain of these traits estimates were derived from regression of progeny average on sire's performance and from intrasire regression of offspring on dam. These estimates are:

Character	Method		
	Half-sib	Offspring-sire	Offspring-dam
Steers			
182 day weight	.08		
Feeder grade	.49	.16	.07
Daily gain	.30	.21	.04
TDN/cwt. gain	1.04	.22	
Slaughter grade	.53	.06	
Carcass grade	.16		
Heifers			
182 day weight	.74		
Feeder grade	.57	.63	
Daily gain	.56	.20	.57
Yearling grade	.20	.002	.32

Genetic correlations among the traits studied estimated from paternal half-sib analysis were as follows:

	Feeder grade	Daily gain	TDN/cwt gain	Slaughter grade	Carcass grade
Steers					
182 day weight	.49	.66	.43	.36	.84
Feeder grade		.28	-.11	.66	.65
Daily gain			-.32	.48	.85
TDN/cwt gain				.18	.16
Slaughter grade					.83
Heifers					
	Feeder grade	Daily gain	Yearling grade		
182 day weight	.31	.51		.50	
Feeder grade		-.0004		.63	
Daily gain				.58	

Heritability of postweaning gain in beef cattle appears to be about one-third. Selecting among potential sires on their own performance should be effective in improving this trait in the offspring. However the sampling error in evaluating a sire's genotype from his own performance is large enough that serious mistakes will be made sometimes. This makes progeny testing of the selected sires desirable.

Heritability of grade seems somewhat higher than heritability of growth rates. It is perhaps around one-third to one-half.

No negative genetic correlations which would handicap selection are evident among the traits studied. (The negative correlation between daily gain and TDN/cwt gain indicates that the more rapidly growing animals consumed less feed per unit of gain.) Initial grade seems to be genetically independent of subsequent gains. Gain in a particular period, however, is highly correlated with grade at the end of the period. Grades at different periods are highly correlated.

Perhaps the most important relationship indicated in the high positive genetic correlation between gain from birth to weaning and postweaning gains. Selection for either trait should be effective in improving the other.

Selection among potential sires on the basis of their own performance on postweaning feeding tests, using an index properly weighted for the heritability and relative economic importance of gains and grade, is suggested as the most effective method of improving these traits in beef cattle. This should be followed by evaluating the progeny at weaning to eliminate mistakes made in evaluating the sire's genotype initially.

GERMINATION AND GERM TUBE DEVELOPMENT OF *PUCCINIA CORONATA* UREDOSPORES¹

Harold Melvin Couey²

Department of Botany and Plant Pathology

An understanding of the uredospore germination process and the subsequent development of the germ tube is fundamental whether the rust organisms are studied as pathogens or are regarded as a problem in microbial nutrition. It had been observed that the uredospores of *Puccinia coronata* Corda avenae F. and L. germinating on a zinc-gelatin substrate formed structures apparently identical to the appressorium, penetration hypha, substomatal vesicle, and infection hyphae formed by this organism during invasion of the host plant. The immediate objective of this study was to examine the role of zinc and of gelatin in germination and vesicle formation.

In previous work optimal vesicle formation had been observed on 3 per cent gelatin in the range of 8 to 10 ppm of zinc (ca 12 to 15×10^{-5} M) at a pH of 6.3 to 6.5. In the present work samples of Difco gelatin differed in their ability to support vesicle formation under these conditions. Increasing the concentration of gelatin increased the zinc requirement for optimal vesicle formation and for inhibition of germination. Water extraction of the gelatin reduced the levels of zinc required for germination inhibition and this toxicity was antagonized by 10^{-3} M magnesium. On gelatin that had been purified by passage through a carboxylic acid resin a similar increase in zinc inhibition

¹Doctoral thesis number 1845, submitted October 4, 1956. Chairman of Committee, Frederick G. Smith, Department of Botany and Plant Pathology.

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of germination was observed and no vesicle formation occurred unless both calcium and magnesium were added with zinc to the purified gelatin at pH 6.5. Calcium and magnesium also antagonized zinc toxicity. These preliminary observations and experiments indicated that gelatin or impurities in the gelatin were modifying the action of zinc.

Germination was then studied on gelatin which had been deionized by passage through a mixed bed resin exchange column. Deionization resulted in increased zinc toxicity and a shift in the acid branch of the pH-germination curve. On whole gelatin some germination occurred from pH 4 to 10 with an optimum range extending from about pH 5 to 9. On deionized gelatin the optimum range was from about pH 7 to 9. Calcium and magnesium antagonized zinc toxicity and shifted the acid branch of the curve back to its original position. The antagonism between calcium and hydrogen ions was evaluated quantitatively in terms of an equilibrium model.

Maximum vesicle formation on deionized gelatin required 12×10^{-5} M zinc, 10^{-4} M calcium or magnesium and a pH of about 8. On whole agar vesicle formation required 12 to 16×10^{-5} M zinc and a pH of 7 to 9. It was also possible to obtain vesicle formation on zinc-amino acid solutions at pH 8. Optimum conditions were 1 to 4×10^{-5} M zinc and 1 to 2×10^{-2} M glycine, alanine or valine at pH 8. No requirement for calcium or magnesium was observed unless much lower concentrations of the amino acids were used. Preliminary evidence indicated that potassium citrate was also capable of inducing vesicle formation.

PREDICTION OF MORTALITY CHARACTERISTICS OF INDUSTRIAL PROPERTY GROUPS¹

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Department of Industrial Engineering

The determination of cost-depreciation policies for industrial properties is normally accomplished with regard to two principal elements. The first is the annual accrual and the second is accrued depreciation. Each of these phases is a function of the retirement behavior of the property, i.e., its mortality dispersion. Consequently, it is extremely desirable to have as complete knowledge of this characteristic as possible when establishing depreciation policy. However, the actual retirement dispersion for a particular group of units is never known until all the items have been retired at which time the need for policy has disappeared. Thus, mortality dispersion is something which must always be predicted for depreciation purposes since the information is needed when the property is installed or at least while a major portion of its components are still in service.

Any prediction of this characteristic is generally found to be more realistic if it can be based upon a study of current retirement experience of similar or like units. The investigation reported in this dissertation was designed to provide a comparison of two of the methods most frequently used to analyze industrial property behavior. These procedures were, first, the use of the Iowa type curves, and second, the fitting of retirement ratios by least squares using orthogonal polynomials. Specifically, the objectives of the study may be stated as follows:

¹Doctoral thesis number 1898, submitted March 15, 1957. Chairman of Committee, J. K. Walkup, Department of Industrial Engineering.

²B.S., Iowa State College, Ames. M.S., ibid. Assistant Professor.

1. To determine an indication of whether either the Iowa type curve method or the use of orthogonal polynomials consistently give better estimates of industrial property mortality patterns.

2. To determine an indication of whether either method gives better results when applied to certain dispersion types, and to data varying in degree of completeness.

3. To determine in particular whether the use of the Iowa type curves causes any significant bias or error in mortality dispersion estimates made of property retirement data varying in shape, length of stub survivor curve, or average service life.

The general outline of the study was to submit the same retirement experience to analyses by both methods and to then compare the corresponding results statistically. Grouping the estimates of a panel of 16 engineers experienced in the use of the Iowa type curves was deemed advisable for the standard curve method because considerable judgment needs to be exercised in matching the data. Only one calculation was accomplished for each orthogonal analysis since the approach is mathematical and, under a given set of conditions, will always produce the same results.

The mortality experience utilized was developed from retirement rate analyses of 27 industrial property accounts and roughly represented 15 of the 18 standard Iowa mortality patterns. While the above studies produced essentially complete life tables, i.e., the per cent surviving ranging from 100 down to 0 per cent, all predictions of expected dispersion patterns were developed from arbitrarily stubbed versions of these data, the terminal points varying from 30 to 90 per cent surviving.

Since the mortality dispersion estimates are used principally for depreciation considerations, the effectiveness of each prediction was measured in terms of the annual accrual and the computed accrued depreciation. The former factor was expressed by the estimate of expected service life, and the latter was represented by a summation of the expectancy-average service life ratios for three selected ages. The expectancy-average service life ratio is recognized as the critical variable in the determination of accrued depreciation under the straight line, average life method. Values of the two terms described above were compared with the corresponding "correct" or standard values based upon the unsmoothed, complete life table data.

The analyses of the mortality dispersion estimates disclosed the following general indications:

1. Under the conditions adopted, i.e., the stipulations for the analysis of the retirement data, the standards assumed, and the comparison bases used, no consistent superiority was enjoyed by either the Iowa type curve method or the use of orthogonal polynomials in estimating mortality dispersion.

2. Based upon the over-all results of this limited study no consistent significant difference in results appears to be attained in basing dispersion estimates on the analysis of retirement ratios as opposed to the use of life table data.

3. The method of orthogonal polynomials showed some advantage in handling experience that could be termed abnormal on the basis of the standard Iowa types, e.g., bimodal data, or a low rate of increase in the size of the retirement ratios at advance ages. This indication was particularly noticeable under extreme stubbing in the case of the accrued depreciation comparison base.

4. The Iowa type curve method tended to produce better estimates of dispersion for the lower modal R- and S-type experiences than did the orthogonal polynomials because of the latter method's failure to predict the relatively rapid termination of experience which is characteristic of these types.

5. The amount of error present in the panel's estimates of left-moded data was, in most instances, significantly reduced as the length of the stub curve was increased.

6. The agreement attained by panel members in their analyses of a particular experience was greatest in the case of the left-moded data and least for the right-moded curves.

7. With one exception all indications of systematic bias in the panel's estimates of left-moded experience were due to underestimation and those for the right-moded experience were due to overestimation.

8. The incidence of significant effects due to stubbing in the bias of the panel's estimates was considerably less than would normally be expected. No indication of consistent significant effect upon the bias of the estimates could be found due to the length of the average service life or mortality type encountered.

SURFACE TENSIONS OF SOME BINARY FUSED SALT SYSTEMS¹

June Lomnes Dahl²

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The surface tensions of seven pure fused salts-- NaNO_3 , KNO_3 , AgNO_3 , LiCl , NaCl , PbCl_2 , and ZnCl_2 --and nine binary mixtures-- NaNO_3 - KNO_3 , AgNO_3 - NaNO_3 , AgNO_3 - KNO_3 , NaCl - KCl , PbCl_2 - LiCl , PbCl_2 - NaCl , PbCl_2 - KCl , PbCl_2 - RbCl , and PbCl_2 - CsCl --were measured by the maximum bubble pressure method. Surface tension showed essentially linear variation with temperature in all cases.

As would be expected, large differences were found between the surface tensions of the pure fused salts. The higher surface tension of molten AgNO_3 compared to NaNO_3 was explained in terms of differences in the polarizability of the metal ions in the melts. The low surface tension of ZnCl_2 was assumed to result from extensive association in this melt.

The surface tension isotherms of the systems NaNO_3 - KNO_3 and NaCl - KCl were found to exhibit small negative deviations from ideality. The greater negative deviations from ideality which were found in the systems AgNO_3 - NaNO_3 and AgNO_3 - KNO_3 were attributed to polarizability differences between the metal ions. The limited data suggested that in binary mixtures of fused salts with a common anion, the deviations of the surface tension isotherms from ideality increase as the differences between the sizes of the replacing cations increase.

Actual minima were observed in the surface tension isotherms of the systems PbCl_2 - KCl , PbCl_2 - RbCl , and PbCl_2 - CsCl ; no minima were observed in the systems PbCl_2 - LiCl and PbCl_2 - NaCl . These minima were attributed to the presence of complex ions or other surface active aggregates in these melts. Other physical measurements strongly support the existence of complex ions, very likely anionic complexes of lead, in the system PbCl_2 - KCl .

The trend in the character of the PbCl_2 -alkali metal chloride surface tension isotherms was shown to be in accord with the fact that any ionic complexes in these melts would be more stable in the presence of large cations with low polarizing power than in the presence of small ions with large polarizing power.

¹Doctoral thesis number 1931, submitted June 7, 1957.

Chairman of Committee, Frederick R. Duke, Department of Chemistry.

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Further evidence for complexing in the PbCl_2 -alkali metal chloride melts was the presence of a yellow color in those melts whose surface tension isotherms exhibited minima; no yellow color was observed in the PbCl_2 -LiCl and PbCl_2 -NaCl systems. This yellow color which persisted in the solid state at high temperatures was found to increase in intensity with increase in the size of the alkali metal ion.

It was pointed out that there is no reason to assume that the complexing in these melts consists only of discrete ions. It was proposed that there are also local aggregations of ions whose structures resemble the structure of the solid state.

STRUCTURES OF SOME POLYNUCLEAR METAL CARBONYLS¹

Lawrence F. Dahl²

Department of Chemistry

A structural investigation of the polynuclear metal carbonyls-- $[\text{Fe}(\text{CO})_4]_3$, $\text{Re}_2(\text{CO})_{10}$, and $\text{Mn}_2(\text{CO})_{10}$, and $\text{Mn}_2(\text{CO})_{10}$ --was undertaken by means of X-ray diffraction techniques.

Iron tetracarbonyl was found to possess monoclinic symmetry; the lattice constants based on a primitive unit cell are:

$$\begin{aligned} a_p &= 8.88 \text{ \AA} \\ b_p &= 11.33 \text{ \AA} \\ c_p &= 8.35 \text{ \AA} \end{aligned} \quad \beta_p = 97^\circ 9.5'$$

There are six $\text{Fe}(\text{CO})_4$ species per unit cell. Systematic absences indicated the centrosymmetric space group $\text{P2}_1/\text{n}$, which would ordinarily require a trimeric molecule to possess a center of symmetry, and would thereby make the iron atoms collinear. The iron atoms should then be located easily by Patterson projections, but this did not turn out to be the case.

The structural analysis proceeded through a complete three-dimensional Patterson and three-dimensional "sharpened" Patterson. The only model at all compatible with this analysis and other evidence, involves a disordered structure in which the iron atoms are arranged at the corners of an equilateral triangle and are randomly placed in each unit cell in one of two orientations approximately differing from one another by a rotation of 60° about the three-fold axis. An iron-iron distance of approximately 2.75 to 2.85 \AA was found. The configuration of the CO ligands still needs to be determined, since it was very difficult to find the carbonyl positions due to the disorder in the structure. An infrared spectral study strongly indicated some association of the carbonyls in the solid state, although the solution spectrum definitely suggested that there are no bridge carbonyls. Three-dimensional Fourier sections computed on X-RAC at Pennsylvania State University appeared to verify the trigonal model, although additional three-dimensional work will be needed to confirm the proposed structure.

On the other hand, no linear arrangement of iron atoms, including the widely accepted D_{2d} structure, can explain the three-dimensional Pattersons. In fact, none of the structures postulated on the basis of the theory of directed

¹Doctoral thesis number 1897, submitted March 15, 1957.

Chairman of Committee, R.E. Rundle, Department of Chemistry.

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valence or on an analysis of the vibrational spectrum appear to be correct.

The rhenium and manganese carbonyls were found to be monoclinic and isomorphous. The lattice constants are as follows:



$$a_0 = 14.70 \text{ \AA}, b_0 = 7.15 \text{ \AA}, c_0 = 14.91 \text{ \AA}, \beta = 106^\circ$$



$$a_0 = 14.16 \text{ \AA}, b_0 = 7.11 \text{ \AA}, c_0 = 14.67 \text{ \AA}, \beta = 105^\circ$$

The space group was determined to be $12/a$ or $1a$; there are four dimers per unit cell. A two-dimensional Fourier analysis of $\text{Mn}_2(\text{CO})_{10}$ revealed that each manganese atom is octahedrally coordinated by five CO ligands and a direct metal-metal bond with another manganese atom, in such a way that the dimeric molecule possesses approximately D_{4d} symmetry (staggered CO's).

These compounds are the first polynuclear carbonyls known to be held together by metal-metal bonds, and, moreover, represent the first real evidence of a metal-metal bond in transition metal complexes stabilized by only metal-metal bonds.

An explanation was given for the long metal-metal distances found (i.e., 2.93 Å for $\text{Mn}_2(\text{CO})_{10}$ and 3.02 Å for $\text{Re}_2(\text{CO})_{10}$) for the compounds as compared to the relatively short iron-iron distance of 2.46 Å for $\text{Fe}_2(\text{CO})_9$.

An infrared vibrational analysis was found to be in agreement with the D_{4d} structure. The molecular structures indicate the validity of the assumption that the 1800 cm^{-1} infrared absorption band is due to bridge carbonyl absorption, since, as the infrared analysis predicted, no absorption bands were observed in this region.

However, there are limitations in the utilization of the partial vibrational infrared analysis in predicting the correct internuclear structures for the metal carbonyls. Although other investigators used such a method to postulate different rhenium and manganese structures, no one predicted the correct structure. The failure of this spectral method in predicting internuclear structures for iron tetracarbonyl is another example of its limitations.

LANDSCAPE RELATIONSHIPS OF THE MARSHALL, DOW AND NAPIER SOIL SERIES¹

Raymond Bryant Daniels²

Department of Agronomy

The purpose of the investigation was to study the influence of landscape evolution on the physical and chemical properties of the soils developed within a watershed. The angular truncation of two or more of the weathering zones of the Iowan-Tazewell loess was presented as evidence of dissection of the area in Latest Wisconsin-Recent time. A radiocarbon sample, from the basal part of a gully fill in the area studied, sampled and dated by other workers, was used to date the valley slopes as Recent. The level to gently convex

¹Doctoral thesis number 1904, submitted April 26, 1957.

Chairman of Committee, Frank Riecken, Department of Agronomy.

²B.S., Iowa State College, Ames. M.S., *ibid*.

Graduate Assistant, Agricultural Experiment Station.

divide positions were dated as Tazewell on the basis of the regional distribution of the weathering zones in the Iowan-Tazewell loess and the buried geomorphic surfaces.

The particle size distribution, total nitrogen, free iron and per cent base saturation of six soil profiles were determined, and petrographic and thin section analyses were made.

The distribution of the soils on the landscape was found to be largely dependent upon the distribution of the geomorphic surfaces and the outcrops of the loess zonation. The per cent base saturation, particle size distribution and free iron contents of the soil profiles studied were found to be related to the age of the surface and the chemical properties of the loess zone from which the soil profile had developed.

The method of combining geomorphic and soil genesis studies was tested and found to be satisfactory.

SYNTHESIS AND STUDIES OF SOME POLYAMINO ACID CHELATING AGENTS¹

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Department of Chemistry

The chelating agent ethylenediaminetetraacetic acid (EDTA) has become, in recent years, an important reagent in the field of analytical chemistry. Its versatility has caused increased interest in other types of amino acids similar to EDTA in structure. This present work was undertaken to synthesize and investigate the chelating properties of an analogous compound ethylenediamine-N,N,N',N'-tetra- α -propionic acid (EDTP). Also studied was the synthesis of a compound similar to EDTA but containing a carboxyl group on each of the two ethylene carbons.

The method developed for the synthesis of EDTP consisted in the alkaline condensation of ethylene diamine with α -chloropropionic acid. The high solubility of the reagent in water required that its separation from the excess reactants be accomplished by precipitating EDTP from a concentrated alcoholic solution with acetone.

The procedure used to prepare α, α' -diaminosuccinic acid consisted of the bromination of fumaric acid, esterification, reaction with potassium phthalimide (Gabriel synthesis), and hydrolysis to yield the desired product. Attempts to prepare α, α' -diaminosuccinic-N,N,N',N'-tetraacetic acid from the above α, α' -diaminosuccinic acid using cyanide and formaldehyde failed as did the condensation reaction with chloroacetic acid. In the latter case however a disubstituted compound was isolated which showed some chelating properties. Any attempt to prepare the desired compound using the reaction between α, α' -dibromosuccinic acid and iminodiacetic acid in alkaline solution also failed, probably due to the elimination of hydrogen bromide from the dibromosuccinic acid.

The ionization constants of EDTP at 25.0°C and an ionic strength of 0.1 were determined from pH titration curves using potassium hydroxide as the titrant. The values determined were

$$pK_1 = 1.89, pK_2 = 2.32, pK_3 = 6.43, \text{ and } pK_4 = 9.27.$$

¹Doctoral thesis number 1819, submitted July 10, 1956.

²Chairman of Committee, Charles A. Goetz, Department of Chemistry.

³B.S., University of Colorado, Boulder.

Graduate Assistant, Industrial Science Research Institute.

The stability constants for several metal chelates of EDTP were determined by a pH titration of EDTP in the presence of a fifteenfold excess of a salt of the metal being studied. Again potassium hydroxide was used as the titrant, the temperature was maintained at 25.0°C, and the ionic strength was 0.1. The metals studied and the corresponding logarithms of their stability constants with EDTP are as follows: magnesium, 3.03; calcium, 2.01; strontium, 1.14; barium, 1.22; zinc, 9.68; cadmium, 8.33; mercury, 8.72; manganese, 6.06; nickel, 11.0; cobalt, 9.70; copper, 13.0; and lead, 9.31.

The major effect of the addition of the four methyl groups as in EDTP compared to the more common EDTA is to greatly reduce the ability of the chelating agent to complex metal ions. This decrease in complexing ability comes from the steric hindrance introduced by the methyl groups. For the same reason EDTP is a stronger acid than EDTA. A secondary effect, much smaller in magnitude, is the one desired, namely the preference of EDTP for smaller ions. This is especially noted with magnesium and calcium. Calcium forms the stronger complex with EDTA but its complex with EDTP is weaker than that of magnesium. This effect can also be seen in the case of cadmium and zinc.

To date no analytical applications for EDTP have been found. The slight shift of the stability constants of metal chelates due to the ion size is not large enough to use analytically. Also the large decrease in metal chelate stability with EDTP over other more common chelating agents is a disadvantage. Two other disadvantages, the costly, low-yield preparation and the instability of aqueous solutions, also hinder the development of analytical uses of EDTP.

CREEL CENSUS TECHNIQUES AND HARVEST OF FISHES IN CLEAR LAKE, IOWA¹

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The Iowa Cooperative Fisheries Research Unit conducted creel census studies at Clear Lake, Iowa in the summer fishing seasons of 1953, 1954, and 1956 and in spring and summer of 1955. The specific problems were: 1) to identify and examine the effects of factors contributing toward variability and bias in estimates derived from creel census data; 2) to determine optimum sampling ratios; and 3) to determine the characteristics of the sport fishing at Clear Lake.

The sampling problems were typical of those associated with many large resort lakes. Ease of access, extensive cottage and resort developments, and the numerous fishing docks and commercial boat landings made sampling of fisherman at the completion of their fishing trips particularly difficult. Thus, most of the contacts were made by patrolling the lake. Anglers were interviewed while they were actually engaged in fishing by Unit biologists. Over the survey periods, approximately 32,500 boat, dock, and bank fishermen and waders were interviewed.

In estimating catch-effort ratios from samples of incomplete fishing trips, two conditions must be satisfied: 1) the rate of catch for anglers who fish a short while must be the same as the rate of catch for those who fish long

¹Doctoral thesis number 1859, submitted December 7, 1956. Chairman of Committee, Kenneth D. Carlander, Department of Zoology and Entomology.

²B.S., University of Massachusetts, Amherst; M.S., Iowa State College, Ames. Graduate Assistant, Industrial Science Research Institute.

periods of time; and 2) the rate of catch must be the same over the last part of the fishing trip as over the first part. For the Clear Lake data no relationship could be demonstrated between rate of catch and length of the fishing trip (correlation coefficients ranged from -0.13 to 0.11). Also, there was no discernible relationship between rate of catch and fraction of the fishing trip completed up to the time of interview. It was concluded that the two requirements were satisfied insofar as the Clear Lake data were concerned. Methods of adjusting for the bias if the two conditions do not hold are discussed.

Estimates of catch per unit of effort and species composition of the catch obtained from incomplete trips were compared with estimates derived from interviews with fishing parties at the end of the fishing trips. It was found that the two methods of contacting anglers gave comparable results.

The rate of catch and level of fishing pressure were found to be negatively correlated. It was concluded that the relationship was indirect rather than direct. Catch per unit of effort was lowest on week end days and highest on weekdays, probably because of an influx of inexperienced anglers on week ends and the tendency for veteran anglers to refrain from fishing when the lake is crowded with other anglers and boating enthusiasts. This points up the necessity of weighting the data if week end days and weekdays are sampled disproportionately.

Sampling errors of the estimated rates of catch for boat anglers ranged from 3 per cent of the mean in 1955 to 12 per cent in 1956. Comparisons of various sampling fractions indicated that little gain in precision is to be expected by sampling more than three days per week over most of the open-water period. Where boat fishermen are concerned, indications are that sample estimates of catch per unit of effort that are within approximately 10 per cent of the actual values may be obtained if the sampling effort is three days per week.

Two methods of estimating angling intensity are described: 1) angler counts stratified by weeks, days, and time of day; and 2) a ratio method requiring a knowledge of the number of rentals from commercial landings and an estimate of the ratio of all fishing boats to livery boats. Angler counts yield estimates of the total number of man-hours of active fishing, whereas the ratio method results in estimates of the total time spent on the lake regardless of how much time is actually devoted to the act of fishing. Angler counts are likely to lead to underestimates of total number of fishing trips and total catch.

The yellow bass dominated the catches made in summer months from 1953 to 1955. Bullhead tended to be most abundant in the creel in spring and early summer. There was a sharp decline in the catch of yellow bass in 1956, probably as a result of a heavy mortality in the fall of 1955. Bluegill have increased in importance in recent years, reflecting a general increase in abundance. Yellow perch have declined in the catch. Walleye and northern pike comprised less than 1 per cent of the total catch in summer months. The over-all rate of catch was about one fish per hour, except in 1956 when the catch per unit of effort was about half that of previous years.

Estimates of the total fishing pressure for 1953 (73 days), 1954 (73 days) and 1955 (142 days), were 60.2, 82.2, and 163.6 angler-hours per acre, respectively.

The total harvest was estimated to be 22.6 pounds per acre in the summer of 1953, 32.0 pounds per acre in 1954, and 66.3 pounds per acre in the spring and summer of 1955.

INTRAFAMILY TRANSFERS OF FARM PROPERTY IN
JEFFERSON COUNTY, IOWA¹Howard Rissell Dorsett²

Department of Economics and Sociology

Many elements of doubt and confusion confront farm families as they seek a satisfactory solution to transferring property within the family. The chief aim of this study was to appraise the methods of overcoming the obstacles underlying these problems. Courthouse records and personal interviews with a random sample of Jefferson County landowners were utilized as sources of data. In the analysis of these data, the success elements of the transfer experiences of the respondents and their deceased relatives were isolated and evaluated as alternative courses of action.

The method of transferring farm property was conditioned by the composition of the landowner's family, the nature and value of farm property owned, and the objectives of the transfer process. Three out of every four respondents had made or intended to make plans for the distribution of their property. The remaining interviewees were satisfied with the distribution as provided by state law.

Eight transfer objectives were studied. The importance of each objective, the problems and major obstacles of the transfer process, and the remedial measures for overcoming these obstacles are indicated in the following discussion.

All of the respondents and 89 per cent of the relatives had the adequate retirement income objective. The respondents regarded the attainment of this objective as more of a problem than had their relatives, for a larger percentage of the respondents expressed nonachievement of this objective. If the respondents and their spouses were to retire with their present net worth from which they could realize a return of five per cent, a retirement income of less than \$200 per month would be received in 63 per cent of the cases. Almost one-third of the respondents had made no plans for retirement. The social security program may enable more retired farmers to achieve an adequate retirement income and may also affect the age and plans for retirement. Even though a majority of the spouses had the power to consume property, this practice of supplementing retirement income was infrequently used. The use of the life estate to assure the spouse's security was less prevalent for the respondents than for the relatives. No plans for a trust were found, but a limited number of the landowners were planning to use the annuity principle to achieve this objective.

Most all of the landowners with two or more children possessed the equitable treatment objective. More of the respondents with plans indicated achievement of this objective than those without plans. This difference was expected since a plan may make allowances for unequal lifetime assistance to children by stipulating an unequal division of the estate. A majority of the landowners had provided for an equal distribution of their estates. A number of these cases reported unequal lifetime assistance to their children. Several of the respondents, who had made improvements at their own expense on farms rented from their parents, also shared the estate equally with the other children. Therefore it was concluded that inequitable treatment could result in those instances where unequal lifetime assistance was followed by an equal distribution of the estate. Parents may achieve this objective by

¹Doctoral thesis number 1866, submitted December 12, 1956. Chairman of Committee, John F. Timmons, Department of Economics and Sociology.

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Graduate Assistant, Agricultural Experiment Station.

regarding the advancements made to certain children as a portion of their inheritance. In other cases of unequal lifetime assistance, bonds of maintenance might be used to pay the children for the care of the parents, or an interest bearing note might be given to the renting child for the improvements constructed at his expense.

The objective of keeping the farm in the family was held by 51 per cent of the respondents. The landowners with plans possessed this objective more often than those without plans. In a majority of cases, the respondents were the first generation of their family to own the land. Actual cases of the farm being sold out of the family were infrequently found; nevertheless, the hypothetical reasons existed and posed a threat to those landowners who desired to achieve this objective. Fifteen of the relatives had made an *inter vivos* transfer to their children and one respondent had included a flexible credit arrangement in his plan to keep the farm in the family.

The objective of minimizing transfer costs was considered by the interviewees to be as important as keeping the farm in the family. A greater proportion of the landowners with plans, compared to those without, desired to minimize costs. Apparently the process of making a plan made the landowners more aware of this objective. The average length of time required to close the estates was 27 months. Less time was used to close the larger estates than the smaller ones. The larger estates tend to be opened sooner and fewer cases of delayed closing were found. The average total cost of settling the estates was \$1603. The average percentage of gross value was 11.16. No evidence was found that a testate distribution results in lower settlement costs. The respondents were unaware of the potential tax burden on their estates. The infrequent use of *inter vivos* transfers indicated a conflict with the retirement income objective. Higher transfer costs may result from friction among the heirs.

The early assistance objective was held by one-third of the landowners with children. A greater proportion of the planning respondents expressed achievement as compared to those without plans. The rate of attainment was associated with the ages of the children. Little difference in the occurrence of early as contrasted to late assistance was found, but early assistance was more beneficial to the children than that received later in life. Farm parents may not achieve this objective because of a conflict with retirement income. In other situations, a desire to treat their children equitably and an age gap of six years may prevent landowners from realizing this goal. More farm families may provide a type of early assistance that does not place heavy demands on limited sources of retirement income. Early planning and a father-son agreement may offset the age difference between the two generations.

The prevention of an excessive debt burden on the purchasing heir was of minor importance, for only five per cent of the landowners held this goal. One-half of the respondents who purchased property in the estate settlement had experienced an excessive debt burden. Equal sharing of the estate among the children increased the debt assumed by the purchasing heir in direct proportion to the number of children. One-third of the planning respondents had made no plans to lighten the debt load because of the equitable treatment objective. Flexible credit provisions and a purchase price based on the true farm value may prevent an excessive debt burden.

The going concern objective was possessed by four of the respondents. Continuous farm production was broken in the settlement of one-third of the relatives' estates; however, the new operator purchased the property of the original operator in all but three of these cases. In one instance, three years were required before the new operator reached the level of production attained by the original operator. The going concern may be interrupted because personal property has to be sold to pay estate settlement costs. Landowners may assure continuous farm production by incorporating farm assets, by making *inter vivos* transfers or by giving the operating heir an option to buy.

The latter action would be less likely to conflict with the equitable treatment and the retirement income objectives.

Maintaining a farm unit of economical size was as important to the respondents as the going concern objective. In two-fifths of the estates studied, land was subdivided during and after the estate settlement. This subdivision was considered excessive, for the farm unit was assumed to be of adequate size upon the landowner's death. Equal distribution of property among the heirs was responsible for most of this division. Only four cases were caused by friction among the heirs and by excessive settlement costs. A family understanding may prevent the division resulting from friction among the heirs. Insurance and savings can provide enough liquid assets to pay the settlement costs. The remedial measures mentioned under the going concern objective are also applicable to this objective.

In conclusion, the respondents were making little use of the alternative means of achieving their transfer objectives. This failure may be attributed to inadequate information regarding the operation and results of these practices. This limitation indicates a need for an educational program to inform farm people of the use and consequences of these courses of action. For those landowners who fail to take positive steps to achieve their objectives, remedial measures could be sought through legislative channels. The possession of conflicting objectives was also a deterrent in the transfer process. Additional studies need to be made of the competitive and complementary associations between transfer objectives. The results of these studies should help farm parents to solve the problems of transferring property within the family.

INHERITANCE OF FLORAL ABNORMALITIES IN ALFALFA¹

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Department of Agronomy

The question of disomic versus tetrasomic inheritance in alfalfa has important theoretical and practical aspects. This question is of theoretical interest in determining whether common alfalfa had an allo- or autopolyploid origin. From a practical standpoint, the rate of inbreeding depression, the ease of addition of desirable genes to established varieties, and the methods necessary for estimating quantitative characteristics of populations vary with the type of inheritance exhibited by a species.

This paper presents the results of study of several types of progenies which segregated for branched raceme and vestigial flower.

Study of Branched Raceme Character

On the basis of F_2 and backcross segregations, Dudley and Wilsie (1) proposed that raceme branching was conditioned by three genes, Br, Ra, and Ra'. It was assumed that Br acted as a tetrasomic gene with chromosome segregation and that Ra and Ra' were the same gene located on chromosomes which had become differentiated and paired in an allopolyploid manner.

To test this hypothesis F_2 and backcross plants were selected from both the normal and branched classes and self-pollinated to produce F_3 and B.C. S_1

¹Doctoral thesis number 1856, submitted December 5, 1956. Chairmen of Committee, C.P. Wilsie and I.J. Johnson, Department of Agronomy.

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progenies. If the proposed hypothesis were correct the F_3 and B.C. S_1 populations derived from F_2 and backcross plants with branched racemes should have shown no normal segregates. Normal F_2 and backcross plants should have produced progenies which would give segregations typical of this hypothesis.

Segregations which were obtained from F_2 plants having branched racemes varied from 1:1 to 1:15. There were also some families which produced no normal segregates. Most normal F_2 plants produced F_3 segregations which varied from 35:1 to 9:7 although one population was obtained in which no plants with branched racemes were found. B.C. S_1 segregations obtained from normal backcross plants varied from 6:1 to 9:7. Segregations from backcross plants having branched racemes ranged from 1:2 to 1:20 with some families producing no normal segregates.

Because the original hypothesis could not explain these results, an alternative hypothesis was proposed. The data indicated that at least one gene in addition to those already proposed was involved and that some more complex gene dosage relationship than that originally proposed was present. Considering these results, the symbols A, Br, Ra, and Ra' were proposed for genes controlling raceme branching. A and Br were assumed to be tetrasomic genes with chromosome segregation; Ra and Ra' were assumed to be duplicate disomic genes. Plants with the genotype BrBr-- and RaRa-- were assumed to be normal regardless of the state of the a locus. Plants with genotypes BrBr--Rarara'ra' or Brbrbrbr RaRa-- were assumed to be normal only if at least 2 dominant A genes were present and plants of genotype Brbrbrbr Rarara'ra' were considered normal only if at least three dominant A genes were present.

F_2 , F_3 , B.C. and B.C. S_1 results were used in establishing this hypothesis. Results from crosses other than the one on which the hypothesis was established supported the hypothesis. The proposed hypothesis was also supported by segregations obtained in S_2 progenies from the normal parent and by F_4 and B.C. S_2 segregations.

Study of Vestigial Flower Character

V, F, and F' were proposed by Dudley and Wilsie (1) as symbols for genes controlling vestigial flower. V was assumed to behave in a tetrasomic manner with chromosome segregation. F and F' were assumed to act as duplicate disomic genes.

To test this hypothesis plants were selected from the normal and vestigial flowered classes in the F_2 and backcross generations and self-pollinated to produce F_3 and B.C. S_1 populations. Normal F_2 plants gave F_3 segregations varying from 6:1 to 1:1.5. Segregations obtained from F_2 plants having vestigial flowers varied from 7:9 to 1:15 with several progenies having no normal segregates. Normal backcross plants produced B.C. S_1 segregations varying from 2:1 to 1:2. Abnormal backcross plants gave segregations which varied from 7:9 to 1:11. There were also some families which produced no normal segregates.

Because the original hypothesis did not satisfactorily explain these results a new hypothesis was proposed. Four genes, D, V, F, and F', were postulated with D and V behaving in a tetrasomic manner and F and F' acting as duplicate disomic genes. Plants of genotype VV-- FF-- were assumed to be normal regardless of the status of the d locus. Plants of genotype VV-- Fff'f', Vvvv FF--, and Vvvv Fff'f' were assumed to be normal only if at least three dominant D genes were present.

As was true for the branched raceme character, F_2 , F_3 , B.C., and B.C. S_1 results were used in establishing this hypothesis. Although no critical test of the hypothesis was available, results from F_4 and B.C. S_2 segregations supported this hypothesis. It was also supported by S_2 segregations of the normal parent and by F_2 and backcross segregations in crosses other than the one discussed here.

Summary

The results of this study indicated that at least four genes were involved in conditioning each of the characters, branched raceme and vestigial flower. In each case it was probable that two of the genes involved were tetrasomic in nature and two behaved as duplicate disomic genes.

The characters, branched raceme and vestigial flower, would be of little practical value as genetic markers because of the complexity of the genetic mechanisms controlling their inheritance.

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MANAGEMENT PRACTICES FOR MAINTENANCE OF
NATIVE PRAIRIE IN IOWA¹

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Only a few isolated tracts of the virgin prairie which once covered five-sixths of the state of Iowa remain intact. Two of these were purchased by the Iowa State Conservation Commission in order to have under control of the state a living museum of the characteristic native prairie landscape and to make available a field laboratory for scientific study.

The objective of this study was to investigate the interactions of the soils, microclimate, and vegetation of the prairie community as affected by various management practices. The practices applied to the Hayden prairie in north-eastern Iowa included several modifications and combinations of complete protection, burning, and mowing. The entire tract was under complete protection from 1945 to 1953, when it was determined that the prairie had passed its highest rate of recovery chiefly because the accumulation of litter and duff exceeded the annual yield of vegetation. The first burning experiment was initiated in March, 1954.

Plants on recently burned areas began growth two to three weeks earlier in the spring than plants on unburned areas. The more rapid rate of growth on burned areas was manifest by the 1955 yields from plots clipped at four different dates during the growing season. The greatest yields obtained from burned plots were from the first clipping (May 30) while the greatest yields obtained from the unburned plots were from the second clipping (July 1). As a result of the advanced growth on the burned areas, the plants reached various stages of maturity at an earlier date than on the unburned areas.

The number and height of flowerstalks of forbs and native grasses were greater in burned than in unburned areas. The number of seedstalks of bluegrass decreased with the frequency and severity of burning. The frequency x abundance of seedstalks of native grasses increased after burning, while

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that of other grasses decreased after burning. By the third growing season after burning, the number and height of flowerstalks of forbs and native grasses were about the same as on the unburned areas. The greater number and height of seedstalks on burned areas may have been caused by the earlier growth of the plants, induced chiefly by higher temperatures and/or by increased availability of certain nutrients, or it may have been caused at least in part by a change in the growth-differentiation balance induced by the accumulation of a greater supply of carbohydrates.

The soil temperature was considerably higher at all depths in the burned than in the unburned areas until July or August, after which date there was essentially no difference. Higher soil temperatures on burned areas were probably due to removal of the insulating effect of the great amount of litter and duff and the darker exposed soil surface. The difference between maximum and minimum air temperature at one inch above the ground was greater on burned than on unburned areas until June, after which there was essentially no difference. Temperature seemed to be the most limiting factor of plant growth between burned and unburned areas during the early part of the growing season.

The available soil water was depleted more rapidly in burned than in unburned areas because of the faster transpiration from the earlier development of the vegetation, and also because of faster evaporation from the soil surface caused by the higher soil temperatures. There was adequate soil moisture for plant growth during the entire growing season for both 1955 and 1956. No difference was noted in soil volume weight or percentage pore space in burned and unburned areas.

A slight increase was noted in the pH of the surface 0.75 inch of soil in recently burned areas. Although available phosphorus as measured in 1956 was low on all areas, a considerable increase was noted on all burned areas. There was essentially no difference in exchangeable potassium or in nitrate production in the top 0.75 inch of soil from burned and unburned areas. Organic matter determinations showed that burning for as much as three consecutive years had no effect on total organic matter in the top six inches of soil.

There was no significant difference in total yield of vegetation from burned and unburned areas. Clipping four times during the growing season reduced yields compared to clipping at the end of the growing season. Frequent clipping for the second consecutive year caused considerable reductions in yields while clipping at the end of the growing season for the second year resulted in only very slight reductions of yields.

Following recovery of the mesic Hayden prairie, complete protection for four to six years after the burning resulted in an accumulation of litter and duff which would equal or exceed the annual yield of vegetation.

Grazing is considered too severe a practice on native prairie in eastern Iowa.

A suitable management plan which would be in keeping with the perpetuation of the native vegetation would be to mow in early autumn approximately two-thirds of the tract every year, leaving certain critical areas unmowed. A management program based on mowing as required, with occasional burning to promote seed production of native species, would probably be more suitable. The prairie should be kept under constant surveillance so that the management plan could be altered in event of any adverse effects which might occur in either the native flora or fauna.

CATION-EXCHANGE EQUILIBRIA ON A SULFONATED
POLYSTYRENE-DIVINYLBENZENE RESIN¹John Morris Erickson²

Department of Chemistry

A study was made of the conditions that exist at equilibrium for the exchange of NH_4^+ and Nd^{+3} between a known external solution and a resin of the sulfonated polystyrene-divinylbenzene type. The resin was Dowex-50-X8 which had been reprocessed to an analytical grade product by Bio-Rad Laboratories of Berkeley, California, and bore their designation, Ag-50-X8. Neodymium was furnished, better than 99.9 per cent pure, by the rare earth separation group of the Ames Laboratory of the Atomic Energy Commission.

Experiments were performed using 13 different equilibrating, or load solutions of known compositions and concentrations. They were prepared from neodymium and ammonium chlorides. Eight of these solutions had a concentration of 1.0 equivalents of total cation per liter (1.0 N) while the other five had 0.1 equivalents of total cation per liter (0.1 N). The ratio, equivalents of NH_4^+ to equivalents of Nd^{+3} , in the 1.0 N solutions varied as follows: 999:1, 995:5, 99:1, 98:2, 95:5, 90:10, 80:20, and 70:30. In the 0.1 N solutions, the ratios were 9995:5, 999:1, 99:1, 95:5, and 60:40.

Thirty-gram samples of the air-dried hydrogen-form resin were loaded into glass columns so designed that they could be weighed on a 200-gram analytical balance at any time during an experiment. At least two columns were used with each load solution so that final equilibrium was attained from two different directions.

The various load solutions were passed through their respective columns until equilibrium was reached. The columns were weighed and then washed free of load solution. The washings were analyzed for chloride ion and from this data the amount of load solution in the column when it was weighed could be determined. The NH_4^+ and Nd^{+3} was eluted off the resin and determined analytically. These data furnished the information from which the amount of water in the resin at equilibrium, over and above that associated with the load solution, could be calculated. Therefore, the amount of NH_4^+ , Nd^{+3} , and water were determined for both the resin phase and the external solution at each equilibrium condition.

The exchange reaction was represented by a single chemical equation showing the ions involved and three different equilibrium "constants" were defined applying mass action law principles. K' was calculated directly from the molalities of the ionic species involved. K'' had the term containing the activity coefficients of the ions of the solution phase, which could be estimated, incorporated in it. The other "constant", $K''_{(N,m)}$ was defined by modifying the usual equilibrium constant equation so that the equivalent fraction of the different species in the resin could be used in the calculation instead of molalities, but keeping the molalities and activity coefficients of the ions in the solution phase. These different "constants" were not constant and the manner in which they varied with resin composition was determined.

Techniques were developed that resulted in the procurement of some precise data for this uni-trivalent exchange system.

The literature on ion-exchange equilibria was reviewed and attempts were made to explain the data obtained in this investigation using the various existing theories, but with little success. It was concluded that considerable more

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data, from independent experiments, must be obtained before all the factors that must be considered in a satisfactory theory, can be adequately evaluated. The relationship existing between the swelling of the resin and the equivalent fraction of an ionic species in the resin must be determined. The various complex ions that conceivably exist in the solution, hence in the resin, must be considered. It is felt that by lumping the effects of the free energy change when the resin swells, and the energy of association (other than electrostatic) of the cations and the resin anions, into the activity coefficients of species in the resin, that these activity coefficients can be defined and determined in a manner that will permit the prediction of behavior within the resin phase. It is hoped that by accurately measuring volume changes, vapor pressures, and other observables, relationships between these quantities and the activity coefficients can be established.

BIOSYNTHESIS AND STRUCTURES OF CORN STARCH¹

Stig Robert Erlander²

Department of Chemistry

A study of the change in properties of corn starch during plant growth has been made. From this study information concerning the structure of starch and its relation to glycogen was obtained.

Starch consists of both a linear component called amylose and a branched component called amylopectin. Since glycogen is also in sweet corn endosperm, the production of starch in sweet corn endosperm involves the three-fold query: how can the highly branched glycogen, the lesser branched amylopectin and the completely unbranched amylose be produced in the same cells and in the same vicinity in these cells? Cumulative evidence seems to point towards glycogen as being an intermediate in the synthesis of starch.

The conversion of glycogen into starch can best be explained by assuming an irreversible debranching of the glycogen followed by the connecting of these linear debranched chains to form amylose. The partially debranched glycogen is amylopectin. The production of longer unbranched chains in the amylopectin allows this partially debranched glycogen and amylose to crystallize out of solution in the form of starch granules, the variation in the rate of crystallization producing the well-known granular rings.

The evaporation of water from the kernel appears to be connected with the synthesis of starch and the proportion of amylose in the starch (1). To study this, some corn ears were covered with cellophane bags during maturation in order to retard the evaporation of water; other ears were husked in order to hasten it.

The mechanism for starch synthesis proposed above involves a simultaneous production of amylopectin and amylose. Because the plant is subjected to diurnal variations, it is possible that amylose is produced during the day and amylopectin during the night. The twelve-hour variations in yield and per cent amylose in corn starch were studied in order to determine if such a process occurs.

In order to study the effect of light on the proportion of amylose, potato plants were grown under three different conditions: a small amount of light, normal daylight, and almost continuous lighting.

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Chairman of Committee, Dexter French, Department of Chemistry.

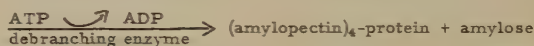
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A study of how starch is produced also involves a study of the structure of the components of starch. A statistical model (2) based on the random condensation of glucose units was developed (3). It is known that all of the 1,4-linkages in amylopectin and glycogen are acid hydrolyzed at nearly the same rate (4). Acid hydrolysis would therefore be a reverse of a random condensation reaction. If amylopectin and glycogen are produced randomly as in a hypothetical condensation reaction instead of all branched molecules having the same structure, they should behave as statistical molecules during acid hydrolysis. Acid degradation studies were therefore made on waxy, dent, and sweet corn glycogen.

The high molecular weights of amylopectin obtained by light scattering methods have been subjected to much criticism. The statistical model predicts that the weight-average molecular weight will be about 100 times the number-average molecular weight. This would account for the discrepancies found in the literature. Some amylopectins were subjected to sedimentation measurements, centrifugation studies (5), variation in the solvent system, and variation in the method of dispersing the granules in order to show that this great difference is not due to the presence of a small amount of extremely large particles.

From the above studies the following sequence of reactions was postulated:



The following conclusions were made:

1. Starch is synthesized from glycogen.
2. A debranching enzyme removes part of the more available exterior and interior branches on glycogen and combines them together to form amylose. A source of energy, perhaps ATP, is required.
3. The greater the degree of branching of the parent glycogen, the greater the asymmetry of the amylopectin.
4. The degree of branching will be less on the amylopectin than on the parent glycogen. The greater the degree of branching, the smaller the difference. Therefore, a high degree of branching is not restricted to glycogen, but the degree of branching of the amylopectin depends on the degree of branching of its parent glycogen.
5. The greater the degree of branching of the parent glycogen, the lower the β -amylolysis limit for the amylopectin.
6. The greater the degree of branching of the amylopectin, the lower the molecular weight of the amylose in corn starch.
7. Amylose and amylopectin are produced at the same time of the day in the starch synthesizing cells.
8. It is postulated that waxy maize endosperm does not normally produce amylose because of the lower degree of branching in its starch and a lower activity of the debranching enzyme. Amylose can be produced by changing the conditions in the cell. It appears that this production of amylose is brought about by increasing the number of receptor groups such as maltose.
9. The \bar{X}_n of waxy starch and the parent glycogen of dent starch remains essentially constant during plant growth, the variation in \bar{M}_w being due to the variation in degree of branching.
10. The \bar{M}_w and \bar{X}_n for sweet corn amylopectin increases with maturity. It is postulated that the high degree of branching in the immature glycogen sterically hinders the phosphorylase enzyme giving a limiting molecular weight for the resulting amylopectin and glycogen.
11. A comparison of the \bar{X}_n for the amylopectins shows that waxy > dent > sweet. This agrees with the phosphorylase activities when amylopectin is the primer (6).

12. The structure of amylopectin and glycogen is between the statistical model and the less random model I (3). These statistical molecules seem to be chemically linked to a protein molecule. The chemical aggregate seems to exist in groups of four.

13. Sedimentation studies show that two components are present in immature waxy maize starch. The nature of the slower component is not known. However, it disappears during maturation and does not appreciably influence the light scattering results. Its molecular weight is in the millions.

14. Centrifugation studies, sedimentation measurements, variation in solvent, and variation in method and dispersing agent show that no physical aggregates are present in amylopectin solutions. The high \overline{M}_w is due to the broad distribution and to chemical aggregates, each aggregate existing as four molecules tied together, perhaps to a protein nucleus.

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DECAY OF SILVER MAPLE (*ACER SACCHARINUM* L.) IN CENTRAL IOWA¹

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Department of Botany

The progress of decay in silver maple (*Acer saccharinum* L.) stands was investigated on three bottomland areas in central Iowa; located in the Ledges State Park, near South Amana, and near Homestead. The sample comprised a total of 845 trees ranging in diameter from 4.0 to 30.9 inches. Trees were included solely on the basis of diameter and chance encounter, regardless of their form or condition. Ages were determined from increment cores extracted at the 1 foot level on the bole.

The increment borer culture technique used to investigate progress of decay in these stands was a modification of the Varner method. An increment core was extracted from the 1 foot level of each tree by means of an increment borer previously sterilized in 1:1000 mercuric chloride. A portion of the heartwood was separated from the extracted core with a pair of flamed scissors and inserted into a flamed test tube containing malt dextrose agar. Flaming was accomplished by means of a portable propane burner. Cultures were transferred to the laboratory and incubated for 3 weeks at 22°C.

Identification of all basidiomycetes isolated from increment cores was attempted unsuccessfully through use of a key based on macro- and microscopic cultural characteristics. The failure to identify any of these fungi was not unexpected as the number of decay fungi included within the cultural key

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was incomplete. To aid in the identification of the various isolates, comparisons were made with cultures obtained from basidiomycetes found fruiting on, or near, silver maple. In this manner six cultures were identified as *Pholiota adiposa* and two as *Polyporus lucidus*. The remainder of the cultures were unidentified.

Trees, from which basidiomycetes or cores exhibiting decay had been extracted, were termed "positives". A total of 148, or 39 per cent, of the trees sampled in the Ledges area, 51, or 25 per cent of those in the South Amana area, and 58, or 22 per cent of those in the Homestead area, were found "positive".

Incidence of basidiomycetes was found to increase with increasing age only in the 90 and 100 plus year age classes. The trend toward increase in incidence with decreasing age, below 90 years, was believed due to expression of vigor rather than of age. Incidence of basidiomycetes was found to decrease with increase in vigor, as expressed by crown class. To study the effect of dbh upon incidence, and to prevent the age factor from affecting the results, the total percentage of "positives" by dbh classes was tabulated only for the 30 and 40 year age classes. An indication of decreasing incidence of "positives" with increasing diameter was noted from the 4 to 16 inch diameter classes, and then again, from the 16 to 22 plus diameter classes.

To determine the extent of decay it was necessary to fell all "positive" trees. The fallen trees were bucked-up and the decay present within the first 16 feet was measured. As the primary purpose of the culture technique was determination of butt rot, decay originating at, or progressing down to the 1 to 3 foot level, was tabulated separately from decay confined to the upper portion of the bole. The full extent of butt rot was measured, regardless of how high is penetrated, and its widest diameter noted. A trend toward increase in extent of butt rot was shown to exist with increase in age, although inconsistencies, possibly due to sample size, were present. Age was associated more with average rate of increase in diameter of decay than with average rate of increase in height. While a general increase in butt rot appeared with increase in dbh class, the trend was not as apparent as that indicated by age. The same over-all trend in decay increase was noted for the entire 16 foot log as it was for the butt. The average extent of decay was small due to the number of "positives" in which visible decay was absent.

External indicators and entrance points for decay fungi were tabulated for the first 16 foot log. They were separated into eight groups and both their frequency of occurrence and average associated height of decay were calculated. These groups were, in order of frequency, swollen knots, seams and scars, open wounds, dead branches, branch stubs, decayed knots, holes, and miscellaneous. Open wounds accounted for the greatest percentage of total resultant rot, followed by the two groups, swollen knots, and seams and scars.

A nondestructive technique, utilizing a Thulium X-ray Unit, was tested for the first time on living trees. A total of 115 exposures was made on trees of varying diameter. Seventeen trees were X-rayed twice, the second exposure being taken at a position approximately 90 degrees from the first, in an effort to more accurately determine defect position. The resultant X-rays were analyzed both visually and with the aid of a densitometer. Defects causing a loss in wood density were indicated on density curves as deviations from a drawn "normal" curve. Cavities and advanced decay present in trees up to 22 inches in diameter were indicated through the use of this technique. The position of bole irregularities, such as involutions and flat faces, correlated well with high density areas found on the exposed film. Decayed areas, if present in the vicinity of these irregularities, usually were masked by the latter. The drawing of a "calculated normal" curve compensated for this masking effect.

EFFECTS OF INHIBITORS ON ALKALINE PHOSPHATASE,
RIBONUCLEIC ACID, AND MORPHOGENESIS IN THE DOWN FEATHER¹Robert John Fabiny²

Department of Zoology and Entomology

Feathers fail to form when embryonic skin from chick embryos of stages 30 to 32⁻ is grown in a culture medium containing approximately 513 $\mu\text{g}/\text{ml}$ of (ethylenedinitrilo)tetraacetic acid (Versene). The development of feathers is only retarded when older explants are treated with the same concentration of this acid. Thus, the size and completeness of form attained by the feather in the presence of Versene are dependent upon the stage of the primordium which is explanted.

Histologically, the Versene-modified feathers have mesodermal pulp which is less compact than that of control feathers. No gross damage to the mesoderm is observed, however, in contrast to the destruction of the pulp reported for beryllium. The epidermis which covers such a feather locus consists of a thin, sometimes flat, layer of cells which is only slightly elevated above the general surface of the skin.

Histochemically, the Versene-modified feathers do not possess the phosphatase-positive reaction in the cytoplasm, nuclei, and nucleoli of their mesodermal cells which is characteristically found in controls. Instead, pale nuclei with only one or two phosphatase-negative nucleoli are noted in cells which do not possess an enzymatic reaction in the cytoplasm. Ribonucleic acid does not accumulate in the cytoplasm of epidermal cells next to the phosphatase-negative pulp. The epidermis which caps the mesodermal locus extends slightly above the level of the adjoining epidermis and its cells lack the basophilia of controls.

The inhibitory effects of Versene can be prevented by treating skin simultaneously with metallic ions and Versene. The presence of MgCl_2 or MnCl_2 (250 $\mu\text{g}/\text{ml}$) in clots which at the same time contained the optimal amount of Versene (513 $\mu\text{g}/\text{ml}$) maintained nearly normal feather growth (i.e., prevented the usual inhibition by Versene). In appearance, the doubly-treated feathers exhibited many features characteristic of controls--a dense mesodermal pulp, strongly positive for alkaline phosphatase capped by an opaque, thick layer of epidermis. The basophilia (due to RNA) in sections of a doubly-treated feather was not as intense as in the epidermis of the control, but did exceed that found in the Versene-treated feather germ.

It is concluded that the inactivation of the enzyme when Versene is added to the feather system markedly affects the synthesis and presence of RNA in the overlying epidermis. The resulting decrease of RNA limits the synthesis of protein and inhibits morphogenesis.

In contrast to Versene which affects the pulp because it chelates metallic ions needed by alkaline phosphatase for its activity, β -2-thienylalanine (β -2-T) specifically inhibits the epidermis. When skin from chick embryos of stages 30 to 33 is grown in a culture medium containing approximately 1.7 to 1.8 mg/ml of β -2-T, feathers are completely inhibited except for mesodermal condensations covered by a thin, flat epidermis. Older feathers are only partially retarded by such a concentration.

Histologically, the epidermal component of completely inhibited feathers is thick and assumes a plano-convex shape, with curved side toward the

¹Doctoral thesis number 1916, submitted May 29, 1957. Chairman of Committee, Howard L. Hamilton, Department of Zoology and Entomology.

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mesoderm. The constituent cells of the epidermis round up and become somewhat irregular in outline. All epidermal cells possess nuclei with only one huge RNA-positive nucleolus, and greatly reduced cytoplasmic RNA. Partially inhibited feathers are sometimes capped with epidermal cells which contain a single large nucleolus. The mesodermal cells of inhibited feathers appear normal when compared with those of controls.

Histochemically, completely inhibited feathers always exhibit a slight phosphatase reaction. Partially inhibited feathers show a moderate to strong reaction depending upon their position in the feather tract and their comparative age within a piece of skin. Such a differential in phosphatase reaction is much less apparent in control cultures, although there are slight differences between feathers of differing age. The disposition of RNA within epidermal cells of the completely inhibited feathers is abnormal. The nuclei contain huge nucleoli filled with RNA. Only occasionally are such abnormal nucleoli observed in partially inhibited feathers, and not at all in controls. The amount of RNA in the cytoplasm is greatly reduced by β -2-T. However, there is still considerable RNA in the inner one-third of the cytoplasm of those cells bounding the mesoderm; the RNA may be bound to phosphate complexes in this region.

The simultaneous addition of L-phenylalanine (1.7 to 1.8 mg/ml) and β -2-T to culture media maintained feather growth. In appearance, the doubly-treated feathers exhibited a dense mesodermal pulp capped with a thick, clear epidermis. The pulp showed a strong phosphatase reaction. Similarly, the epidermis possessed accumulations of basophilic granules in all cells, particularly in those cells adjacent to the mesodermal pulp. These feathers were indistinguishable from normal controls.

It is suggested that β -2-T acts either by (a) preventing the release of RNA from the nucleolus to the cytoplasm or (b) antagonizing the utilization of RNA during the synthesis of peptides and proteins.

MILK SERUM EQUILIBRIA AS SHOWN BY DIALYSIS, ULTRAFILTRATION AND ULTRACENTRIFUGATION. I.¹

Cecil Garfield Fortney, Jr.²

Department of Dairy and Food Technology

Introduction

The initial objectives of this study were to evaluate the ionic equilibria (including caseinate) of milk, by use of resin membrane electrodes (5) and dialysis techniques. Difficulties encountered with both, led to the development of "pressure dialysis" and relatively simple ultrafiltration apparatus and techniques. These techniques, together with ultracentrifugation, were employed to: (1) separate milk centrifugally into several components (unheated centrifugal skim milk (UCS), unheated centrifugal whey (UCW), a lipid component (not studied), unheated native caseinate (UNC) and centrifugal cream (not studied)); (2) determine dialyzable inorganic constituents in unheated whole milk (Aug. 1955 through Mar. 1956); (3) determine inorganic constituents, dialyzable from UCS, UCW, and washed, reconstituted UNC; (4) evaluate, in a preliminary way, effect of pasteurization temperatures on dialyzable constituents of whole milk; (5) evaluate inorganic constituents in ultrafiltrates

¹Doctoral thesis number 1822, submitted July 11, 1956.

Chairman of Committee, Emerson W. Bird, Department of Dairy Industry.

²B.S., Iowa State College, Ames. M.S., ibid. Instructor, Dairy Industry.

from UCS and UCW; (6) determine major inorganic constituents in unheated, bulked, whole milk (April 1955 through March 1956); and (7) determine the phosphoric acid presumably esterified with the OH groups in hydroxy amino acids (nuclear phosphorus), which had been prepared by acid precipitation from washed UNC or from UCS.

Methods Employed

The analytical methods, employed for the various inorganic constituents of milk, were: Na (7), K (6), Ca and Mg (4), Cl (2), and inorganic P (3).

The electrodes employed contained the cationic resin rod of Kressman (5) and were fabricated and used in a manner similar to that of Carr (1).

Results

Methods developed

The chloride determination developed (2) was found to recover an average of 97.8 per cent of the chloride added to milk.

The continuous pressure dialysis procedure (2), employing a pressure of 115 mm Hg (on a mineral oil layer placed above the sample), yielded a maximum weight change (of the sample in the sac) of ± 4.0 g during 15 hours; maximum gain occurred at 7 hours and maximum loss at 15 hours. The method removed 93.9 per cent of the osmotically active (freezing points of original sample and residue) in 15 hours.

The ultrafiltration method (2) permitted filtration of 60 ml in 55-60 hours (4.4°C). Consecutive 10 ml aliquots of filtrate yielded identical contents of inorganic constituents.

Inorganic constituents of milk and its fractions

The average inorganic content of unheated whole milk, during one calendar year (April 1955 through March 1956), were: Na 560.1, K 1584.6, Ca 1387.1, Cl 1181.8, and inorganic P 722.9 mg/100 g solids-not-fat.

Nuclear P was lower, when casein was prepared from washed UNC (0.511 per cent) than when prepared from UCS (0.555 per cent).

Pasteurization of milk (62.8°C, 30 min) affected only the amounts of Ca and Mg dialyzed; the former decreased, as expected, but, contrary to expectation, the latter increased.

Average constituents, dialyzed from whole milk during August 1955 through March 1956, are: Na, K, Cl 100, Ca 24.9, Mg 36.6, and inorganic P 61.3 per cent of the total in the milk.

The average percentages of the total inorganic constituents in whole milk that appeared in its centrifugal whey are: Na, K, and Cl 100, Ca 42.0, Mg 87.8 and inorganic P 64.1.

The dialyzable constituents of unheated whole milk and its centrifugal whey were studied. The percentages of Na, K, Cl, and Ca which dialyzed from the two products were the same, viz., Na 100, K 100, Cl 100, and Ca 24.9 per cent of the amount in the unheated milk. All of the Mg (87.8 per cent) and inorganic P (64.1 per cent) dialyzed from UCW, whereas but 36.6 (Mg) and 61.3 (inorganic P) dialyzed from the unheated whole milk. These data suggest either a sequestering action or an adsorption by caseinates, when the whole milk is dialyzed.

Adaptation of cationic, resin-membrane electrodes to measurement of ionic equilibria in milk does not seem feasible because of ionic interferences.

Summary

Methods for determining Cl in milk, for continuous pressure dialysis and for ultrafiltration of milk were developed.

Averages of inorganic constituents (Na, K, Ca, Mg, and inorganic P) of

milk were reported as mg/100 g solids-not-fat, for one calendar year.

Nuclear P was found to be lower in iso-electric caseins, prepared from washed, centrifugal, native caseinates than from the companion skim milk.

Average values were presented for constituents dialyzed from unheated whole milks. The constituents dialyzed from unheated whole milk and its centrifugal whey were compared.

The percentages of the inorganic constituents, present in unheated whole milk, that appear in the centrifugal whey, were presented.

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DIFFERENCES IN LITTER SIZE AND GROWTH RATE AMONG PUREBRED AND CROSSBRED SWINE¹

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The objectives of this study were to expand the knowledge about breeding systems in general and to answer questions pertaining to specific breeds and crosses and reciprocal crosses.

The characteristics studied were litter size at birth, 56 and 154 days, and average weight per pig in the litter at 56 and 154 days.

Litter size was consistently greater at the Ankeny farm while growth rate was superior at the Napier farm. Seasonal influences also had marked effects, although some of the variation due to this source could be described by a linear increase in both litter size and weight.

Age of dam was also an important source of variation in all characteristics, 154-day old litters of gilts averaging 0.7 pigs smaller than those of yearling or older sows and 7.8 pounds less per pig.

¹Doctoral thesis number 1912, submitted May 27, 1957.

Chairmen of Committee, L.N. Hazel, Department of Animal Husbandry and John W. Gowen, Department of Genetics.

²B.S., Agricultural and Mechanical College of Texas, College Station.
M.S., ibid. Graduate Assistant, Agricultural Experiment Station.

In view of the above facts, the first step in the study was to correct the data to eliminate the effects of season, farm, and age of dam so that litters from sows that farrowed in different seasons, on different farms, and at different ages could be compared fairly. These corrections were computed by fitting constants.

The various analyses of variance yielded the following conclusions:

1. Crossbred Landrace-Poland pigs were superior in growth rate to pigs of the two breeds. 595 litters were used. Crossing Landrace boars on Poland sows gave results much inferior to crossing Poland boars on Landrace sows.

2. Crossbred sows were superior to purebred sows in litter size at all ages. Landrace-Poland sows were superior to other combinations of crossbreds involving later generations of crossbreeding with Duroc, Chester White and Hampshire breeding. 1360 litters were used.

3. Comparison of LxP and PxL sows failed to demonstrate any difference in inherited maternal effect due to the way in which the two breeds were originally crossed. 466 litters were involved.

4. Nine inbred lines of Poland boars when topcrossed on Landrace sows yielded significant differences between the lines for 154-day weight and litter size at birth. In these topcrosses the lines ranked in approximately the same order of merit as in earlier test matings on sows of Poland breeding. 83 litters were available for this comparison.

5. The statistical significance of differences between boars of the Beltsville strains, the Yorkshire and Hampshire breeds was doubtful, but the Hampshire and Yorkshire breeds did rank above the Beltsville strains in the final amount of marketable product. 136 litters were used.

6. Using a fourth breed of boar on Duroc-Poland-Landrace sows gave results superior to the use of one of the two breeds originally used to start the cross when the fourth breed was Yorkshire, Hampshire or Montana No. 1. However, the poorest results in total litter production resulted when the Chester White was used as the fourth breed. 246 litters were involved.

7. Chester White boars sired litters that averaged one-half pig larger at birth but one-fourth pig smaller at 56 and 154 days than those sired by Duroc boars. Sows used were of Landrace-Poland breeding, and 276 litters were concerned. Litters by Duroc boars were also heavier in average weight per pig at both 56 and 154 days.

8. Variance components were estimated and expressed as fractions of the sums of components for each trait. The error components made up from 82 to 95 per cent of the totals.

It appears possible to attain high production and to maintain it through subsequent generations by a system of rotational crossbreeding using several breeds of boars upon succeeding generations of crossbred sows. Using the Landrace in the early stages of the crossbreeding system had definite advantages because of the high production of crossbred Landrace sows. Initiating the system with Landrace sows was superior to reversing the sexes with the same breeds.

Phenotypic correlation coefficients among the five performance traits measured were computed, using all 1360 litters involved in the study. Correlations between the three measures of litter size were large, positive, and highly significant. Those of litter size at birth with average 56 and 154-day weights were negative, but the situation was reversed at later ages. There was no correlation between litter size at 56 days and 56-day weight, but a positive correlation existed between litter size at 56 days and 154-day weight. A positive correlation of .68 existed between average 56-day weight and average 154-day weight of the litter.

RELATIVE IMPORTANCE OF EPISTATIC AND NONEPISTATIC
GENE EFFECTS IN MAIZE¹Edwin Ernest Gamble²

Department of Agronomy

The relative importance of epistatic and nonepistatic gene action in the inheritance of a quantitative trait has not been determined. Most of the previous studies concerned with differentiating the type of gene action in the inheritance of a quantitative trait have assumed that epistatic gene action was negligible. An evaluation of the relative importance of epistatic and nonepistatic effects in the inheritance of quantitative characters would be useful for the following reasons: (1) as an indication of the bias in results obtained from genetic models assuming no epistasis, (2) as an indication of the importance of epistasis in the basic genetic mechanisms, and (3) as an indication of the best plant breeding techniques to be used in a breeding program.

The study reported herein was undertaken to provide information of the relative importance of nonepistatic and epistatic gene action in certain quantitative traits of corn. Individual plant data were collected on six inbred lines of corn, their 15 single crosses (F_1 's), 15 F_2 's, and 30 backcrosses. The traits measured were yield, plant height, kernel row number, ear length, ear diameter, and weight of 100 kernels. The material was grown at two locations and in two years. The stability of epistatic and nonepistatic gene effects over different environments was considered. The frequency of occurrence of each inbred line in the crosses exhibiting significant epistasis in the inheritance of the characters was evaluated. In addition, a comparison was made between the incidence of epistasis and the degree of heterosis in a cross.

The relative importance of epistatic and nonepistatic gene action for the material studied was determined using the factorial gene model developed by Anderson and Kempthorne (1954). The factorial gene model permits the estimation of six parameters, namely, K_2 , E, F, G, L, and M, where: K_2 is the contribution due to the over-all mean plus the locus effects and interactions of the fixed loci, E and F are the contributions due to the variable effects plus the interaction of these locus effects with the fixed loci (the nonepistatic effects), and G, L, and M are the contributions due to the interaction of all possible pairs of variable loci plus the interaction of these interactions with the fixed loci (the epistatic effects). Second order and higher interactions were assumed negligible.

Significance of the parameters and a comparison of the absolute magnitude of the epistatic and nonepistatic parameters were used to determine the relative importance of each type of gene action. Both nonepistatic and epistatic gene action were important in the inheritance of all the characters studied, but nonepistatic gene action was relatively more important. Epistatic gene action was slightly less important relative to nonepistatic gene action for the character yield than for the other characters in the material studied.

When combined analyses of the four experiments were made epistatic gene action was apparently less important relative to nonepistatic gene action than in the case of analysis of individual experiments. The magnitude of the nonepistatic parameters varied only slightly among the four experiments while the magnitude of the epistatic parameters varied considerably over the four experiments. The results suggested that epistatic gene action was influenced more by environmental effects than was nonepistatic gene action.

¹Doctoral thesis number 1901, submitted April 3, 1957. Chairmen of Committee, G.F. Sprague and I.J. Johnson, Department of Agronomy.

²B.S.A., Ontario Agricultural College, Guelph, Canada. M.S.A., *ibid.* Graduate Assistant, Agricultural Experiment Station.

Differences occurred in the crosses for the incidence of epistatic gene action in the inheritance of the characters considered. Evaluation of the frequency of occurrence of each inbred line in the crosses exhibiting epistatic effects in the inheritance of the characters indicated that some inbred lines contributed more epistatic gene action than others. For instance, the inbred, B36, contributed much of the epistatic gene action to the inheritance of all six characters while the inbred, WF9, contributed little epistasis to any of the characters. Other inbred lines were important for their contribution of epistatic gene action in certain characters but were of lesser importance for other characters. The inbred, Hy, was particularly important in contributing epistatic gene action in the inheritance of plant height.

A comparison was made between the incidence of epistasis and the degree of heterosis in a cross. This comparison indicated a fairly good relation between the incidence of epistasis and the degree of heterosis in a cross. In general, if a cross exhibited epistatic gene action in the inheritance of a character, a high degree of heterosis was expressed in that cross.

LABORATORY METHODS FOR IDENTIFICATION OF VARIETIES OF SOYBEANS AND OATS¹

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Department of Botany and Plant Pathology

Laboratory tests for varietal identification are needed in conjunction with purity and germination tests to adequately determine the quality of seed. Such tests have several obvious advantages over field plantings. However, satisfactory procedures for identifying crop varieties in the laboratory have not been devised. This study was therefore conducted with the following objectives: (a) to develop procedures for identifying varieties of soybeans and oats in the laboratory and (b) to evaluate techniques which may form the basis of identification systems for other self-pollinated crops.

Tabulations were made of distinctly qualitative morphological characters of the seeds and seedlings of each of 80 soybean and 116 oat varieties. Useful characters for distinguishing soybean varieties include seed coat color, hilum color, hypocotyl color, and type of pubescence. Seed size and leaf shape are of minor value only. Certain oat varieties or groups of varieties may be distinguished by the presence or absence of pubescence on the sheath and leaf blade. Seedling colors are distinctive in some instances. Seed characters are less diagnostic, primarily possessing descriptive value.

Since many varieties cannot be distinguished by morphological characters alone, differential reactions to various physical, physiological, and pathological tests were investigated. Oat varieties can be divided into two major groups on the basis of fluorescence of the lemma, but possess no distinctive differences in root fluorescence. The fluorescence test was of little diagnostic value for soybeans; seeds and seedling roots were all fluorescent except for a single variety in which the roots were nonfluorescent. Root fluorescence in soybeans was shown to be a simple recessive character.

Physiological tests such as photoperiod and diffusion pressure deficit measurements of seeds proved to be of little value for distinguishing varieties

¹Doctoral thesis number 1899, submitted March 16, 1957. Chairman of Committee, Duane Isely, Department of Botany and Plant Pathology.

²B.S., Iowa State College, Ames. M.S., *ibid*.
Graduate Assistant, Agricultural Experiment Station.

of oats. Their usefulness for any self-pollinated crop will probably be limited.

Pathological tests were invaluable in distinguishing morphologically similar varieties of both soybeans and oats. Oat varieties were separated by their reactions to Helminthosporium victoriae, races 7, 7A, and 8 of stem rust (Puccinia graminis avenae Erikss. and Henn.) and races 203, 216, and 232 of crown rust (P. coronata Corda var. avenae, F. and L.). Further distinctions can probably be made through the use of additional races of crown rust.

The application of disease resistance in soybeans to varietal determination was demonstrated for the first time. Isolates of the downy mildew pathogen (Peronospora manshurica (Naoum.) Syd.) were obtained from plants systemically infected from oospore-encrusted seeds. The various isolates were identified by their reactions on a set of 14 differential varieties. An isolate from Illinois differed in reaction from the six previously described races and was tentatively called race 7. Isolates from Indiana, Missouri, and three locations in Iowa reacted similarly on the differentials and were tentatively referred to as race 8. Race 5 was isolated from a collection of seed obtained from Georgia. Races 1 and 2, originally described by their reactions on three differential varieties, were redefined using the enlarged set of 14 differentials. Eighty varieties were tested for their reaction to races 5, 7, and 8, with varietal reactions rated according to a set of five infection types.

These three races were extremely useful in identifying morphologically similar varieties.

The usefulness of pathological tests for determining varieties of soybeans and oats suggests similar application in other crops. Prerequisites for such tests are the availability of pathogens which are obligate parasites and which contain several physiologic forms.

Satisfactory laboratory determinations of self-pollinated crops should be feasible if based on a combination of qualitative characters (morphological, physical, physiological, and pathological) of seeds and seedlings. Laboratory determination of varieties of cross-pollinated crops will, however, present difficulties, because of intravarietal variation. Since different varieties may include identical population elements, it is not possible to make identification specific to a single seed or seedling. Rather, it may be possible only to base judgments on the average response of the population of plants to a single character.

Identification procedures as above described should be useful in three different areas of seed work: seed certification, seed inspection with respect to seed law enforcement, and in seed testing.

CHROMOSOME BREAKAGE BY MALEIC HYDRAZIDE AND
MALEIC HYDRAZIDE DERIVATIVES IN STRAINS OF
MAIZE WITH DIFFERENT KNOB NUMBERS¹Gerard Emiel Graf²

Department of Genetics

The hypothesis that maleic hydrazide causes breakage selectively in heterochromatin has been tested. Four varieties of maize with different numbers of heterochromatic knobs were treated with maleic hydrazide and N-acetyl maleic hydrazide and the resulting anaphase bridges were counted. The varieties Zapalote Chica (12 knobs), HY (6 knobs), IDT (4 knobs), and knobless flint (0 knobs), were tested. A strong positive correlation was found between knob number and anaphase bridges after chemical treatment. The differences between Zapalote Chico and knobless flint were approximately fivefold for all chemical treatments. These data are interpreted as supporting the hypothesis. X-ray treatments of 100 roentgens and 250 roentgens appeared to cause equal numbers of bridges in all four varieties and definitely did not indicate a positive correlation between knob number and X-ray induced bridges. Thus, it appears that there is a fundamental difference between X-ray and maleic hydrazide induced chromosome breakage.

It has been demonstrated that the N-acetyl, N-caproyl, and N-benzoyl derivatives of maleic hydrazide cause considerable chromosome breakage relative to maleic hydrazide. Among these derivatives activity seems to be positively related with the size of the side chain.

The hypothesis that maleic hydrazide causes chromosome breakage due to reactivity with sulfhydryl groups has been supported by the finding that glutathione antagonizes the chromosome breaking action of maleic hydrazide. However, the related compound N-ethyl maleimide, which is very reactive with sulfhydryl groups, did not cause significant chromosome breakage.

Carlson's finding that maleic hydrazide causes persistent nucleoli in maize has been confirmed. It was found that the N-derivatives of maleic hydrazide tested also caused persistent nucleoli.

¹Doctoral thesis number 1817, submitted July 9, 1956.

Chairman of Committee, Joseph G. O'Mara, Department of Genetics.

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COMPETITION BETWEEN CORN AND WEEDS¹Winston Philip Hackbarth²

Department of Botany

The objective of this investigation was to study the effects of weed competition on the growth and yield of corn under different environmental conditions. Weed control experiments in progress were utilized to obtain information on the effect of weeds on growth and yield of corn. On the basis of these results, field experiments were devised to investigate the interaction of factors in corn-weed competition, and greenhouse experiments were designed to investigate the effects of separate factors.

The twelve weed control practices used in these studies ranged from three normal cultivations to no cultivation, with supplemental spray applications. Treatments based on three cultivations resulted in better weed control and higher corn yields than other treatments in the first year of the study. Substitution of an adequate pre-emergence spray treatment for one cultivation did not significantly reduce corn growth and yield. In the experiments of the second year, under conditions of above normal rainfall and below normal temperature, the corn was reduced in plant size and yield approximately 18 per cent. Under these conditions adequate spray treatments gave better results than those based on three cultivations. Strip spraying was not significantly better than over-all spraying.

In experiments to test weed control with and without cultivation, the hand-weeded plots averaged 50 per cent greater yield of corn than the unweeded plots, independent of cultivation treatment. Corn height and yield in the plots were reduced proportionately as weed yields increased. Correlation coefficients between corn yields and heights, corn yields and numbers of leaves, and corn heights and numbers of leaves were 0.96, 0.97, and 0.99 respectively.

Early season weed control was important in preventing weed establishment and its effects on corn yields. Omission of the second cultivation caused no increase in weeds or reduction in corn yield, whereas, omission of the first cultivation increased weed yield and decreased the corn yield. Removal of weeds at progressively later stages of the corn development caused proportionately more reduction in yield. Cultivation with inner shovels removed to prevent corn root injury significantly lowered corn yield because of high weed infestation.

Field comparisons at high infestation rates were made between annual grasses, Setaria spp., and broad-leaf weeds, Amaranthus spp., as competitors with corn. The weed yields in pounds per acre of Setaria, Setaria-Amaranthus mixture and Amaranthus were 4691, 4276, and 3954 respectively. Corn yield was reduced by Setaria from 111.9 bushels per acre in the weeded plots to 9.8 bushels per acre. Yield was reduced by the Setaria-Amaranthus mixture from 97.4 to 15.8 and by Amaranthus from 100.3 to 31.8. The suppression of the corn growth by the heavy infestations of weeds is indicated by the increase in stalk-ear ratio: 0.43 in the weeded plots, 0.59 in the Amaranthus plots, 1.42 in the mixed weed plots and 2.44 in the Setaria plots.

Greenhouse studies of the factors affecting weed competition with corn were made, using Abutilon theophrasti Medic. and Setaria glauca (L.) Beauv. at two rates of infestation and four combinations involving two water levels and two fertility levels. Differences between the high and low levels of fertility and moisture were statistically significant, both in corn and weed yields. Setaria

¹Doctoral thesis number 1841, submitted August 16, 1956.

Chairman of Committee, J.M. Aikman, Department of Botany.

²B.A., State University of Iowa, Iowa City. B.S., Idaho State College, Moscow. Graduate Assistant, Agricultural Experiment Station.

was a more effective competitor with corn than was Abutilon in terms of weed yield and reduction in growth of the corn.

In the low fertility-low moisture combinations it was difficult to ascertain which factor had become limiting first. With increase of moisture alone to the higher level, there was an increase in yield of dry matter, whereas with increase of fertility alone to the higher level, there was no significant increase in yield. Light was also a limiting factor due to the winter greenhouse conditions.

MOLECULAR CALCULATIONS BY THE ONE-CENTER METHOD¹

Stanley Hagstrom²

Department of Chemistry

The use of the one-center method for the direct calculation of total energies of simple or highly symmetric molecules has been investigated. The one-center method for molecules is aimed primarily at eliminating the calculation of many-center integrals such as occur in the conventional methods by replacing the usual set of atomic orbitals centered on the various atoms of a molecule by a more extensive set of basis functions centered at a single point. Problems of polycentric integrals then naturally do not arise, and the only two-center integrals are the relatively simple nuclear attraction integrals. Application of the method has been to the hydrogen molecule and the triatomic hydrogen molecule ion, H_3^+ , using an extensive "superposition of configurations" formed from the complete orthonormal set of orbitals.

$$(2z)^{3/2} \left[\frac{(n-q-1)!}{(n+q+1)!} \right]^{1/2} (-zr)^q L_{n+q+1}^{2q+2} (2zr) e^{-zr} Y_{qm}(\theta, \varphi),$$

where L are the Laguerre polynomials, Y_{qm} are the ordinary (complex) spherical harmonics, and z , n , q , and m are adjustable parameters chosen to provide the most rapid convergence in the energy.

In general, the calculated energy values are comparable in accuracy to those obtained with conventional methods which involve the use of atomic orbitals. The results suggest that extensions to somewhat more complex cases (such as H_3 or LiH) are probably possible and well within the reach of computing machines now available. Extension to still more complicated cases (such as H_2O , NH_3 , He_2 , etc.) involving inner shell electrons off the expansion center of more than three or four electrons does not seem to be practical.

In the case of H_2 at an internuclear distance of 1.4 a.u., the calculated energy was -1.151 a.u. for a 38-term expansion without angular dependence and -1.161 a.u. for a 44-term expansion including angular dependence. This latter value represents the second best calculated energy for this system to date. Although not investigated in as great detail, calculations on H_3^+ indicate that good results could be obtained by this method for this system also.

Generally speaking, the convergence of the one-center expansion is slow. In view of this slow convergence and from a detailed examination of the calculated wave function in the case of H_2 , it is concluded that highly accurate

¹Doctoral thesis number 1911, submitted May 24, 1957.

Chairman of Committee, Robert S. Hansen, Department of Chemistry.

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calculations are not feasible by this method. Moreover, as shown by the H_2^+ results, the convergence becomes slower as the internuclear separations become larger. The various factors affecting the convergence have been considered in detail.

A one-center calculation on H_2 previously advanced by Huzinaga as support for the one-center approach has been shown to be in error.

The numerical calculations were divided into three relatively independent stages: (i) evaluation of all required one and two electron integrals over the given set of basis functions, (ii) compilation of the final energy matrix elements between the various configurations from the basic integrals, and (iii) diagonalization of the configuration interaction matrix. The IBM 650 computer was programmed to carry out the principal computational processes involved in these stages. Routines for calculating the two-center nuclear attraction and the electron repulsion integrals, a compiling routine for the configuration interaction matrix elements, and eigenvalue routines for the partial or complete diagonalization of the configuration interaction matrix were constructed and are described in detail.

HOST SPECIALIZATION IN *PYTHIUM GRAMINICOLUM* AND
PATHOGENICITY OF *P. GRAMINICOLUM* TO FOUR HOST
SPECIES IN SOIL AMENDED WITH NITROGEN AND PHOSPHORUS¹

Richard Owen Hampton²

Department of Botany

Part I. Host Specialization in *Pythium graminicolum*

Pythium graminicolum was isolated from the roots of crops grown in continuously cropped and rotation cropped soils. Six such crop isolates were individually exposed, in potted soil, to the passage of eight seedling generations of three varieties of their corresponding host crop. (Soil to be planted to oat varieties was infested with a corn isolate, since *P. graminicolum* was not isolated from the roots of field-grown oats.) *Pythium graminicolum* was isolated from plants of each variety following the eighth seedling generation.

The resulting 18 variety isolates were tested for specialization on the same crop varieties from which they were isolated.

A degree of host specialization was demonstrated among isolate-origin groups and among individual crop isolates.

Generally, corn, oat, and *Setaria* isolates were more virulent on corn, oats, and *Setaria* than were isolates from wheat, barley, and rye; while wheat, barley, and rye isolates were more virulent on barley and rye.

Of the instances of specialization among individual crop isolates, the most consistently expressed examples among all sources of variation were between isolates from corn and rye and between isolates from corn and barley.

Fifty per cent of all interaction classes involved in the comparison of two given crop isolates on their respective and opposite host crops were "positive" in effect. This frequency was greater in interactions involving only isolates from different origin groups. The corn, oat, and *Setaria* isolates composed the "continuously-cropped" origin-groups, while the wheat, barley, and rye isolates composed the "rotation-cropped" origin-group.

¹Doctoral thesis number 1882, submitted February 19, 1957.

Chairman of Committee, W.F. Buchholtz, Department of Botany.

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Virulence of variety isolates was not significantly influenced by the level of resistance of crop varieties with which they were associated during exposure to the eight seedling generations.

Variety isolates were equivalently differentiated on host-crop groups. Likewise, differentiation between isolate-origin groups was equivalent among crop varieties.

Part II. Effect of Soil Infestation by P. graminicolum on Plant Responses to Applied Nitrogen and Phosphorus

Fresh weight determinations were made of four-week-old corn, wheat, oat, and barley plants which had been grown in noninfested and Pythium-infested soils receiving different levels of nitrogen and phosphorus in three separate experiments. An evaluation of the response of these crops to added nitrogen and phosphorus in the absence and in the presence of Pythium graminicolum indicated that in most cases these nutrient amendments did not affect plant susceptibility. Instead, responses to both nitrogen and phosphorus were, in general, of lower magnitude in Pythium-infested than in noninfested soil.

Magnitude of responses to applied nutrients among crops in Pythium-infested soil as well as the relative magnitude of plant weights in noninfested and Pythium-infested soil were conditioned by susceptibility to P. graminicolum. Oats and barley were resistant while corn and wheat were susceptible to P. graminicolum. Oats and barley rather consistently responded in greater magnitude to applied nitrogen and phosphorus in Pythium-infested soil than did corn and wheat. In each of three experiments corn failed to respond significantly to nitrogen or phosphorus applied singly or in combination in Pythium-infested soil. While responses to singular applications of either nitrogen or phosphorus in wheat, oat, and barley plants growing in Pythium-infested soil were seldom significant, plants of these crops responded significantly in Pythium-infested soil to combined applications of these nutrients.

Weights of oat and barley plants receiving nitrogen and phosphorus in Pythium-infested soil in experiment three were greater than the weights of plants receiving no added nutrients in noninfested soil. This effect was not dependent upon fertilizer-conditioned changes in resistance. Instead, these two resistant crops were able to respond significantly to added nutrients despite the presence of Pythium graminicolum.

The ratios of nitrogen to phosphorus in nutrient amendments resulting in maximum plant weights in Pythium-infested soil were not characteristically different from those of amendments producing maximum responses in noninfested soil.

Part III. Seasonal Occurrence of Pythium graminicolum on the Roots of Field-Grown Corn in 1956

The frequency of recovery of Pythium graminicolum from the roots of field-grown corn was determined at 11 times during the corn growing season of 1956. Pythium graminicolum reached recovery frequency maxima in early June (37.5 per cent) and early September (15.8 per cent). Failure to recover P. graminicolum in late July and early August was associated with scarce midsummer precipitation and high daily soil temperature maxima.

Pythium graminicolum was not isolated from the roots of field-grown corn plants less than 14 days nor more than 132 days of age.

The recovery frequency of Fusarium species from corn roots was recorded four times during the 1956 corn growing season. The combined frequencies of these species ranged from 75 per cent on May 22 to 55 per cent on Sept. 22.

Pythium graminicolum was recovered predominantly from young, vigorous roots, nearly healthy in appearance. This fungus was recovered three times from crown internode tissue. Fusarium species were the predominant fungi cultured from field-grown corn roots during the 1956 corn growing season.

STABILIZATION OF IOWA LOESS WITH PORTLAND CEMENT¹Richard L. Handy²

Departments of Geology and of Civil Engineering

One of the more difficult problems in modern road construction is finding sufficient aggregates for the base course. In a highway or secondary road the surfacing takes the wear, but the base course carries the load and transmits it to the subgrade. The base course must have strength, and it must be stable during seasonal wet-dry and freezing and thawing conditions. Base courses often consist of aggregate or soil and aggregate mixtures. In areas of critical aggregate shortage an alternative method is to mix soil with Portland cement, add water, and compact it with rollers or similar equipment. This construction, known as soil-cement, is one of the earliest and most successful methods of chemical soil stabilization, and roads constructed of soil-cement have been in use since 1935.

Although there has been some soil-cement construction in Iowa, it is not known just how applicable this method might be in different areas of the state. Part I of this thesis gives the results of laboratory tests which define minimum cement requirements for various soils in Iowa. The soil material tested was loess, a silt deposit of widespread abundance. The properties of loess vary over the state, and sampling was done in three areas which have already been studied in some detail. These areas are in southwestern, east-central, and northeastern Iowa. Samples were obtained to represent the widespread range in properties of loess, and to represent the different soil horizons of the major loessal soil series in the three areas. Correlation of cement requirements to soil series was made, and it was found that Portland Cement stabilization would be practicable and economical particularly for the coarser loess materials. Many of the medium-textured loess materials show an extreme sensitivity to freezing and thawing, and stabilization of these materials would not be economical. With more clayey loessal soils the frost sensitivity is reduced, but these soils still are not very economical to stabilize.

A theory is proposed to account for the extreme frost sensitive nature of certain samples on the basis of basic property data such as particle size and clay occurrence. The theory is believed to offer a solid basis for further research to reduce frost susceptibility, and it should apply to other methods of stabilization as well. Briefly, the theory involves moisture movement and saturation of pores during freezing, so that subsequent ice expansion forces grains apart and breaks the cementation bonds. In coarse loess the final freezing water apparently is not confined sufficiently for a build up of high pressures. On the other hand in clayey loess the permeability is reduced so that less saturation occurs during freezing; the frost sensitivity is reduced but not eliminated completely. Frost resistance depends to a large extent on the mode of occurrence of clay in the loess; clay as aggregates behave much like silt.

Part II of this thesis described the theoretical development and laboratory evidence for a mechanism of cementation in loess, the cementation being exclusive of the well-known cation-exchange and flocculation effects which occur almost immediately on mixing. The long-term cementation is believed to be partly due to pozzolanic reactions between alkali and silt grains, and it is demonstrated that the reaction can be improved by raising the pH. Therefore

¹Doctoral thesis number 1814, submitted June 26, 1956.

Chairmen of Committee, Chalmer J. Roy, Department of Geology and Donald T. Davidson, Department of Civil Engineering.

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the use of high alkali cement may actually be preferred in many kinds of soil-cement, including loess-cement. On the basis of companion studies and correlations with petrographic analyses it is believed that the alkali reaction may proceed best with quartz, although this is not known for certain. The same possibility is suggested from theoretical considerations of the probable surface chemistry of common soil minerals, based on mineral structures and the use of the polarization theory of Weyl. It was this theoretical aspect, along with chemical evidences of solubility and geologic evidences of the cementing in sandstones, which first led the author to suspect significant alkali reactions with quartz. Similar reactions with more reactive silicas such as opal or glass have been known for some time and were the basis for the early Roman cements composed of lime and volcanic ash. The fact that this pozzolanic reaction can proceed in the relatively inert loess is indicated by the development of considerable cementation in loess mixed only with sodium hydroxide solutions. The alkali reaction is consistent with data on lime-loess stabilization described in another report. A possible practical application of the alkali effect is indicated by a 15 per cent gain in strength from the external application of a sodium hydroxide solution during curing. At its present development this procedure is on the borderline economically.

SOME LOW TEMPERATURE MAGNETIC AND THERMAL PROPERTIES OF THE CHROMIUM(III) HALIDES¹

Wilford Nels Hansen²

Department of Chemistry

The paramagnetic susceptibilities of the chromium(III) halides have been measured as a function of temperature using the Gouy method with powdered samples. Measurements were made on CrF_3 and CrCl_3 from 300°K to 60°K and on CrBr_3 and CrI_3 from 400°K to -1°K. All of these salts were found to follow the Curie-Weiss law over a considerable temperature range. The Curie-Weiss law is $1/\chi_M^* = (T - \theta)/C_M$ where χ_M^* is the molar susceptibility corrected for diamagnetic contributions, θ is the paramagnetic Curie temperature, and C_M is the Curie constant. The effective magnetic moment per molecule was calculated from the formula, P_{eff} (Bohr magnetons) = 2.839 (C_M). The value observed for the temperature above which the Curie-Weiss law holds and the values of θ , C_M , and P_{eff} for each compound given are: for CrF_3 , 140°K, -124°, 1.85, and 3.86; for CrCl_3 , 100°K, 31°, 1.70, and 3.70; for CrBr_3 , 120°K, 51°, 1.94, and 3.95; and for CrI_3 , 150°K, 70°, 2.03, and 4.04. As the temperature is lowered all of the $1/\chi_M^*$ vs. T curves begin to curve away from the T axis. For CrF_3 , χ_M^* suddenly becomes very large below 70°K. Apparently CrF_3 becomes ferromagnetic at this temperature. The curves of the other salts approach the temperature axis asymptotically. The data obtained confirms work on CrCl_3 by Woltjer (1) and on CrF_3 by Bizette and Tsai (2).

The heat capacities of CrCl_3 and CrF_3 were measured calorimetrically between about 15°K and 300°K. In addition to the direct experimental data, values of heat capacity, entropy, enthalpy, and free energy are tabulated at selected temperatures. The values of entropy and enthalpy at 298.15°K are: for CrCl_3 ,

¹Doctoral thesis number 1827, submitted July 13, 1956.

Chairman of Committee, R.E. Rundle, Department of Chemistry.

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$S^\circ = 29.38 \pm 0.10$ cal. deg.⁻¹ mole⁻¹ and $H^\circ - H_0^\circ = 4217 \pm 5$ cal. mole⁻¹; for CrF_3 , $S^\circ = 22.44 \pm 0.03$ cal. deg.⁻¹ mole⁻¹ and $H^\circ - H_0^\circ = 3357 \pm 4$ cal. mole⁻¹. The lattice contribution to the heat capacity has been estimated by the method suggested by Tauer and Weiss (3). CrF_3 and CrCl_3 exhibit heat capacity maxima associated with ferromagnetic ordering at 69.8°K and 16.8°K respectively. CrF_3 exhibits an additional maximum at 45.64°K. The origin of the latter anomaly is uncertain, but is assumed to be magnetic. Graphs showing the electronic entropy change as a function of temperature are given for CrF_3 and CrCl_3 . The heat capacity data for CrCl_3 are in qualitative agreement with earlier work by Trapeznikova, *et al.* (4) and Anderson (5). The heat capacity of CrF_3 has not been previously measured.

The magnetization curves of CrF_3 , CrBr_3 , and CrI_3 were determined at 4.2°K by measuring the intensity of magnetization periodically as the field was cycled between 15,850 gauss and -15,850 gauss. CrF_3 exhibits hysteresis with a remanent moment of 0.036 Bohr magnetons per chromium atom and a saturation moment in agreement with the value 0.12 obtained by Henry, *et al.* (6). CrF_3 is evidently ferrimagnetic. The data for CrBr_3 indicates no hysteresis. Below 300 gauss the intensity of magnetization is strictly linear with field corresponding to a molar susceptibility of 6.98 cgs units/oersted/mole in this region. At 5000 gauss the magnetization is 86 per cent of the expected value of 3.00 β /molecule. CrI_3 shows a large hysteresis coupled with magnetic hardness. It exhibits a remanent moment of 0.34 β /molecule and a coercive force of 1300 gauss. At 14,500 gauss the magnetization is only one-third of the expected saturation value.

Measurements of remanence in CrF_3 from 4.2°K to 65°K indicated no change of trend near the lower maximum in the heat capacity curve.

Some correlations are made between the magnetic and thermal observations and the known crystal structures of CrCl_3 , CrBr_3 , and CrI_3 .

The method developed for measuring the magnetization curves at low temperatures is described. Measurements of the magnetization of the sample are made in a homogeneous field by observing the current through a solenoid around the sample necessary to give a magnetic moment equal and opposite to that of the sample. The null point is detected by a small quartz-fiber torsion balance mounted outside the cryostat. On one arm of the torsion balance is mounted a small piece of iron which is attracted or repelled by the sample plus solenoid. The null point is determined by adjusting the solenoid current until no deflection of the balance is observed when the sample plus solenoid is moved (the balance arm supports a mirror and its position is determined with a telescope and lighted scale). This method was shown to be useful for other types of measurements. It was shown that the method could be used to measure magnetic susceptibilities of paramagnetic powders at room temperature with an accuracy of about 0.1 per cent. The method will permit the detailed study of ferromagnetic substances at low fields. Details of the method are discussed and further applications suggested.

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BURSTING SPEED OF ROTATING DISCS¹Harold Alexander Heckart²

Department of Mathematics

In many of the applications of rotating discs, such as gas turbines, it is desirable to be able to specify the angular speed at which the disc will fail catastrophically. For angular speeds approaching that at which such failure will take place, the material is in a state of strain which is considerably greater than those for which the material obeys Hooke's law. In order to calculate the bursting speed it is therefore necessary to have recourse to a theory of plasticity.

There are two general theories of strain hardening plasticity which are in common use. The deformation theory which assumes a unique relation between stress and strain, and the flow theory which assumes a unique relation with stress and strain rate. In this investigation, the flow theory is used. It is assumed that elastic strains may be neglected in comparison with the plastic strains, and, in accordance with empirical evidence, that the material is incompressible during plastic deformation.

Tresca's yield condition and the associated flow rule are first applied to the problem, and it is found that this yield condition must apparently be restricted to the problem of the annular disc. Such an annular disc is considered, in which the inner radius is one-half the outer radius of the disc, and the thickness of the disc is given by $H = cr^k$, where h is the thickness, r the radial distance to the considered point, and c and k are constants. The material is assumed to be AL 24S-T4 aluminum and bursting speeds are calculated for selected values of k ranging from $k = -2$ to $k = 2$. It is found that the bursting speed varies by some 31 per cent for this range of values of k . Thus the bursting speed is not too sensitive to the variation in disc thickness.

Von Mises' yield condition and the associated stress-strain-rate relations are next applied to the problem. Under the assumption that the strain hardening is a function of the distortion, the yield condition may be expressed as:

$$S_r^2 - S_r S_\theta + S_\theta^2 = f^2 \left[\sqrt{6/3} \int \sqrt{d\epsilon_{ij}} d\epsilon_{ij} \right], \quad (1)$$

where S_r and S_θ are conventional radial and tangential stresses, respectively, f is the function relating simple tensile stress to the resulting tensile strain and $d\epsilon_{ij}$ are the plastic strain increments; the integration being performed over the strain path followed in arriving at the considered state. In accordance with the previous assumption that the elastic strains may be neglected in comparison with the plastic strains, the stress-strain-rate relations of Von Mises are used, rather than those of Prandtl-Reuss. For plane stress of an incompressible material, the stress-strain rate relations of Von Mises reduce to the single relation:

$$(2S_\theta - S_r) \delta \epsilon_r / \delta \omega = (2S_r - S_\theta) \delta \epsilon_\theta / \delta \omega, \quad (2)$$

where ϵ_r and ϵ_θ are conventional radial and tangential strains, respectively, and ω is angular speed.

A compatibility relation is found, which may be written as:

$$\epsilon_r = d(r\epsilon_\theta)/dr. \quad (3)$$

¹Doctoral thesis number 1909, submitted May 15, 1957.

Chairman of Committee, Harry J. Weiss, Department of Mathematics.

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In addition, the equilibrium equation may be written as:

$$d(hrS_r)/dr = hS_\theta - \rho h\omega^2 r^2(1 - \epsilon_\theta). \quad (4)$$

Equations (1), (2), (3), and (4) comprise a system of four equations for the four unknowns, S_r , S_θ , ϵ_r , and ϵ_θ . This system may be solved numerically, and a plot made of central tangential strain versus angular speed. The maximum of this curve indicates the angular speed for which the central tangential strain may increase indefinitely without further increase in angular speed. This angular speed should, then, be that at which the disc will burst.

Calculations are carried through for a solid disc with constant initial thickness, and the material is assumed to be AL 24S-T4 aluminum. Experimental evidence shows that the bursting speed is reduced approximately in proportion to the percentage of material removed in forming an annular disc. By means of this experimental evidence, the bursting speed of the solid disc as computed using Von Mises' yield condition is compared with that of the annular disc as computed using Tresca's yield condition. It is found that these agree to within about 7 per cent, which the author considers to be in good agreement.

ESTIMATION OF THE PARAMETERS OF A POPULATION FROM A MULTI-CENSORED SAMPLE¹

G. Ronald Herd²

Department of Statistics

The specific problems in this thesis were the estimation of parameters of univariate populations from samples where multiple points of censorship occur. The case of a sample subjected to multiple points of censorship (on the right) may be described as follows: A sample of n items is tested; when the first one fails at time x_1 , a random sample of k_1 is withdrawn from the $n-1$ items still in test; the remaining items are observed until the second item fails at time x_2 , when k_2 items are withdrawn; and the process of withdrawing a prescribed number k_i at the time x_i when the i -th failure occurs continues until the r -th failure occurs at time x_r , at which time the remainder of the items are withdrawn.

The method of maximum likelihood is employed to estimate the parameters for the exponential, the normal, and the gamma distributions. These estimates are, in certain cases, difficult to obtain. They require iteration; therefore, certain practical limitations exist for their use. A new method of solving the likelihood equations for the normal distribution is introduced, and a Δ function is tabulated to facilitate the solution. An extension of the censorship procedure to another general type is considered for estimation by the method of maximum likelihood.

The nonparametric estimate of the probability of surviving (quantiles) is obtained, and a general method of estimation based on the quantiles is presented, which will yield reasonable results when the method of maximum likelihood cannot be used, and which will be reasonably efficient in comparison to the maximum likelihood estimates when these are available for comparison. It is shown that the method of estimation from the quantiles yields the maximum likelihood estimate for the exponential distribution for all rules of censorship

¹Doctoral thesis number 1879, submitted December 17, 1956.

Chairman of Committee, H.O. Hartley, Department of Statistics.

²A.B., University of Kansas, Lawrence. M.S., *ibid*.

and the uniform distribution for a random sample. The quantile method is asymptotically equivalent to the methods of maximum likelihood for the parameters of the normal distribution. The method yields a simple result (best linear unbiased estimate) for the uniform distribution with single or multi-censorship. This is an advantage over the maximum-likelihood method, which does not furnish a simple result.

The above results are illustrated by a number of examples taken from industrial experiments. It is possible, through the techniques presented, to utilize small samples such as exist in industry, and also, although curtailment exists, to have assurance of a certain number of complete "life times" from which to make estimates even where no prior knowledge--other than the distributional form--exists on the "life times" of the items tested.

ALKALINE PHOSPHATASE OF THE DEVELOPING DOWN FEATHER:
SUBSTRATES, ACTIVATORS, AND INHIBITORS¹

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Sodium glycerophosphate, disodium p-nitrophenyl phosphate, glucose-1-phosphate, glucose-6-phosphate, hexose diphosphate, fructose-6-phosphate, muscle adenylic acid, and yeast adenylic acid were used as substrates to determine whether one or more alkaline phosphatases were present in the developing down feather. The pattern of activity was the same with all substrates except yeast adenylic acid, although the intensity of the reaction varied with the various substrates. With yeast adenylic acid there was a reduction in enzymatic activity but with epidermal activity confined primarily to the nucleoli of the cells. Phosphatase was found in the nucleoli, chromatin granules, nuclear membrane, and cytoplasm of the cells in the mesodermal pulp. In the epidermis, phosphatase was present in the nucleoli of the cells of the barbs and in the nucleus and cytoplasm of the cylinder cells.

To determine whether these differences in reactivity were due to different phosphatases, the activating or inhibiting effects of Mg^{++} , Mn^{++} , Be^{++} , Zn^{++} , Fe^{+++} , $HAso_4^-$, $HAso_3^-$, CN^- , semicarbazide, iodoacetate, Versene, glycine, alanine, cysteine, histidine, methionine, proline, valine, serine, lysine, and arginine were studied in conjunction with several of the substrates. Mg^{++} was necessary for activity with muscle adenylic acid, hexose diphosphate, and fructose-6-phosphate. At high concentrations, Zn^{++} inhibited activity with all substrates except fructose-6-phosphate, and in low concentration stimulated activity with yeast adenylic acid. Yeast adenylic acid showed strong nuclear activity at concentrations of arsenate which inhibited activity with all other substrates. Versene, iodoacetate, semicarbazide, Be^{++} , and CN^- in high concentrations inhibited phosphatase activity. Mn^{++} , Fe^{+++} , and $HAso_3^-$ had no apparent effect on phosphatase. Cysteine and histidine had a greater inhibitory effect on phosphatase than the other amino acids. At low concentrations, glycine promoted activity with muscle adenylic acid. Valine, proline, and methionine in low concentrations gave some indications of possible stimulation of activity with sodium glycerophosphate.

The activity of phosphatase with yeast adenylic acid differed from that with

¹Doctoral thesis number 1918, submitted May 31, 1957. Chairman of Committee, Howard L. Hamilton, Department of Zoology and Entomology.

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muscle adenylic acid in its response to some of the inhibitors and activators. The activity with both of the adenylic acids differed from that obtained with sodium glycerophosphate. The fructose sugars were inhibited by lower concentrations of the chemicals than inhibited activity with sodium glycerophosphate. Epidermal phosphatase showed a greater sensitivity to the inhibiting agents than the phosphatase in the pulp. Cytoplasmic phosphatase was more easily inhibited than that in the nucleoli.

These data indicate that the nucleolus is the source of at least part of the phosphatase. They also suggest that the developing down feather contains more than one phosphatase capable of utilizing the various substrates at a pH of 9.0-9.4.

DISTRIBUTION OF LOADS IN BEAM-AND-SLAB BRIDGES¹

Robert Marion Holcomb²

Department of Civil Engineering

A new procedure for predicting the strains and deflections of the beams in simple-span beam-and-slab bridges of the usual proportions has been developed. It divides the calculations into two primary steps:

1. Temporary reactions are assumed at the beams to prevent deflections of the beams, and the loads are distributed to these reactions by the slab acting as a continuous beam.
2. The temporary reactions are removed and the consequent effects on the beams are computed.

Since no deflections or moments are produced in the beams in step 1, the entire effect on the beams is found in step 2. This effect on a beam is assumed to be that of a loading consisting of:

1. A concentrated or narrowly distributed force, the temporary reaction reversed, and
2. A widely distributed force produced by the resistance of the slab to deformation.

Part 2 of the beam loading has been assumed to be sinusoidal, but any other form could be assumed. For the bridges tested the effects of part 2 are relatively small; so the precision of the predictions of maximum strains and deflections is not sensitive to changes in the form assumed.

It is suggested that, pending further study, the use of the procedure be limited to bridges having a ratio of span to beam spacing of 2 or more, and also a ratio of beam to slab stiffness, H of 2 or more.

To obtain checks on the predictions by the proposed procedure, by the present (1956) AASHO specifications, and by the tentative revisions (T-15-50), four bridges were tested. Two are full-size bridges in use on a highway; their spans are 41.25 ft and 71.25 ft, and their roadways are 30 ft wide. The other two were built in a laboratory. They include crown, curbs, and diaphragms; their spans are 10 ft and 25 ft, and their roadways are 10 ft wide. Each of the four bridges has four beams equally spaced, has the interior beams larger than the exterior, and is of composite construction. Among the four bridges the span to spacing ratio varied from 3.1 to 7.8, and the beam stiffness to slab stiffness ratio varied from 3.0 to 10.7. The loads on the

¹Doctoral thesis number 1863, submitted December 11, 1956.

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laboratory bridges were either single-axle or tandem-axle trucks; either one truck, alone, or two side by side. The load on the highway bridges was a single semi-trailer truck having tandem rear axles.

Strains and deflections were measured at a number of locations at each bridge for various positions of the loads. Of these test results, those of most interest to designers and those directly comparable to the predictions under the specifications are the maximum strains caused by a given loading when it may be placed in any position. Comparing the predicted maximum strains with those observed, the ranges in per cent of error for all the beams, both interior and exterior, are:

Proposed procedure	+11 to -10
AASHO	+87 to -8
T-15	+106 to +5

It is concluded that the proposed procedure provides improved predictions under a much wider range of conditions than does either specification method. To understand and use it requires no special training, and the time required for its use is only about one hour per analysis; so it should be practical for practicing engineers to use it. It lends itself readily to refinement through further research, and a number of subjects for further research are recommended.

It is further concluded that the present AASHO specifications provide what may be regarded as acceptable predictions of the effects of two trucks side by side, +30 to -8 per cent error, but may be grossly in error in predicting the effects of a single truck, +87 to +5 per cent error. The tentative revisions are grossly in error in predicting the maximum effect of two trucks on an exterior beam, +106 to +51 per cent, as well as in predicting the effects of a single truck, +90 to +34 per cent error.

SOME CORRELATIONS OF CARBAZOLE DERIVATIVES WITH RELATED HETEROCYCLES¹

Julian Bernard Honeycutt, Jr.²

Department of Chemistry

The purpose of this investigation was to prepare some aromatic and heterocyclic derivatives of carbazole for testing as liquid solution scintillators and to synthesize certain boron-containing carbazoles, particularly azo dyes, for potential use in brain tumor therapy. Another objective was to determine whether or not certain reactions followed the same course with carbazole, or substituted carbazoles, as with related heterocycles.

Refluxing a mixture of carbazole, *p*-bromobiphenyl, anhydrous potassium carbonate, copper bronze and petroleum ether (b.p. 190-210°) or 12 hours gave a 13 per cent yield of 9-*p*-biphenylcarbazole, m.p. 224-226°. Similarly, *p*-bis-(9-carbazolyl)-benzene, melting at 320-322°, was obtained in 39 per cent yield from *p*-diiodobenzene. 2-Bromopyridine gave 13 per cent of 9-2'-pyridylcarbazole, m.p. 93-95°, under the same conditions except that iodine was added to the reaction mixture. By the same procedure using

¹Doctoral thesis number 1828, submitted July 13, 1956.

Chairman of Committee, Henry Gilman, Department of Chemistry.

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nitrobenzene as the solvent instead of petroleum ether, a 13 per cent yield of 4,4'-bis-(9-carbazolyl)-biphenyl, m.p. 282.5-284°, was obtained from 4,4'-dibromobiphenyl. Refluxing a mixture of carbazole, potassium carbonate, copper bronze, iodine and 2-chloroquinoline gave 10 per cent of 9-2'-quinolyl-carbazole melting at 93-94°. Attempts to prepare 9-(*p*-dimethylaminophenyl)-carbazole from carbazole and *p*-bromodimethylaniline in various solvents, or without a solvent, were unsuccessful. It was found that 2-halopyridines and 2-chloroquinoline would not condense with carbazole in an alkaline acetone solution as do alkyl iodides and acyl halides.

In order to determine how reactive a diazonium salt must be in order to couple with 9-ethylcarbazole, several electro-negatively substituted benzene-diazonium salts were reacted with 9-ethylcarbazole in acetic acid or ethanol. Diazotized 2,4-dinitroaniline gave a small yield of 3-(2,4-dinitrophenylazo)-9-ethylcarbazole, m.p. 214-215° (dec.), and *p*-nitrobenzenediazonium chloride yielded a small amount of 3-(*p*-nitrophenylazo)-9-ethylcarbazole melting at 183-184°. *o*-Nitro, *o*-bromo, *p*-bromo-, and *p*-carboxyaniline gave diazonium salts which did not form dyes with 9-ethylcarbazole. The use of pyridine as a solvent or the utilization of Nekal Ba-75 as an emulsifying agent for the 9-ethylcarbazole did not promote the formation of the desired dyes from *o*- and *p*-bromoaniline. Thus, it is concluded that for reaction with 9-ethylcarbazole a diazonium salt must be at least as reactive as *p*-nitrobenzenediazonium chloride.

9-Ethylcarbazole-3-diazonium chloride reacted with phenol in an alkaline solution to give a yellow compound, m.p. 130-132° (dec.), which did not analyze correctly for 3-(*p*-hydroxyphenylazo)-9-ethylcarbazole or for a disazo compound. The infrared spectrum, however, indicated that an N=N linkage was present. With β -naphthol, diazotized 3-amino-9-ethylcarbazole gave a maroon solid which was purified by chromatography on a Celite-silicic acid column to give a 19 per cent yield of 3-(2-hydroxy-1-naphthylazo)-9-ethylcarbazole, m.p. 179-181°. The diazonium chloride from 3-amino-9-ethylcarbazole apparently reacted with an alkaline solution of *o*-hydroxybenzeneboronic acid anhydride as indicated by the progressive color change in the reaction mixture. The crude product of the various runs ranged in color from yellow-brown to black. No satisfactory recrystallization solvent, or solvent pair, could be found. Attempted chromatographic purification failed to give anything but tars or oil. The reaction between diazotized 9-(*o*-aminophenyl)-carbazole and *o*-hydroxybenzeneboronic acid anhydride likewise gave a product which could not be purified.

9-Ethyl-3-carbazolyl lithium (1) added to tri-*n*-butyl borate at -65° and the mixture hydrolyzed gave a 4.7 per cent yield of 9-ethylcarbazole-3-boronic acid melting at 236-238°. Similar reactions designed to prepare 9-ethylcarbazole-1-boronic acid were fruitless. The only product isolated was 9-ethylcarbazole.

Reactions at room temperature between carbazole or 9-ethylcarbazole and boron trifluoride etherate yielded only starting materials. Gaseous boron trichloride slowly bubbled into a cool benzene solution of 9-ethylcarbazole gave a pale green solid which melted partially at 88-91° and nearly completely at 165-169°. A small particle had not melted at 300°. Attempted recrystallization from benzene left boric acid as the residue and returned no solid from the solution.

3-Amino-9-ethylcarbazole in benzene treated with a slight excess of acetic anhydride gave a 73.5 per cent yield of 3-acetamido-9-ethylcarbazole melting at 198-199° (2). The amine in benzene containing a little pyridine yielded 54.5 per cent of 3-benzamide-9-ethylcarbazole, m.p. 187-188 (2) when treated with benzoyl chloride. The acetamido derivative and slightly less than an equivalent amount of fuming nitric acid in glacial acetic acid gave a 27.0 per cent yield of 3-acetamido-4-nitro-9-ethylcarbazole, m.p. 188-189.5°. Excess fuming nitric acid produced a yellow compound melting at 268-270° which on analysis gave results between those calculated for dinitro- and trinitro-

acetamido-9-ethylcarbazole. It is believed that the major product is 3-acetamido-4,6-dinitro-9-ethylcarbazole. Nitration of 3-benzamido-9-ethylcarbazole yielded two products, an orange solid melting above 250° which could not be purified and an orange solid which after several recrystallizations gave a small amount of material melting at 201.5-202.5°.

In an attempt to find reactions potentially useful in structure proof work, carbazole and 9-ethylcarbazole were refluxed in purified dioxane with metallic lithium. Termination of the reaction by either carbonation or hydrolysis gave only starting materials. Refluxing a mixture of 9-ethylcarbazole and concentrated hydriodic acid for 72 hours resulted in a 99.4 per cent recovery of 9-ethylcarbazole. 10-Ethylphenothiazine under the same conditions gave an 85.9 per cent yield of phenothiazine.

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TREATMENT OF WESTERN PHOSPHATE ROCKS TO IMPROVE ACIDULATION CHARACTERISTICS¹

William Henry Honstead²

Department of Chemical Engineering

Four methods of treating western phosphate rocks to improve their acidulation characteristics were investigated. The methods were (1) washing with water, (2) calcination, (3) grinding followed by air separation, and (4) froth flotation with a cationic collector. Two western rocks were used for these tests. These were both obtained from the Anaconda Copper Company's mine at Conda, Idaho. One was a foot-wall rock; the other was a hanging-wall rock. These were considered to be fairly representative of the phosphate rocks from southeastern Idaho.

A high grade Florida land pebble containing 35.5 per cent P_2O_5 and a hand-picked sample of rock from the Simplot mine at Fort Hall, Idaho containing 35.8 per cent P_2O_5 were used for comparing the acidulation characteristics of the treated rocks.

The ground rocks were acidulated with sulfuric acid at weight ratios of H_2SO_4 to P_2O_5 of 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, and 2.0. A 6-inch casserole was used for mixing. The samples were then poured into a pint fruit jar and stored for 30 days in a cabinet held at a constant temperature of 100°F and a constant humidity of either 70 per cent or 25 per cent.

Samples cured at the higher humidity had high moisture contents, low P_2O_5 conversions, and very poor physical properties. Curing at 25 per cent humidity resulted in products having high P_2O_5 conversions and good physical properties.

In the washing treatment a sample of ground phosphate rock was placed in a two-inch diameter vertical glass tube four feet long. Water was passed upward through the tube at various velocities and for various lengths of time.

¹Doctoral thesis number 1877, submitted December 17, 1956.

Chairman of Committee, D.R. Boylan, Department of Chemical Engineering.

²B.S., Kansas State College, Manhattan. M.S., *ibid.*

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The rock remaining in the tube was recovered and dried as an underflow stream. The overflow was also recovered and dried. The P_2O_5 content of the underflow was higher than that of the overflow, while the R_2O_3 content of the underflow was less than one-third that of the overflow. Superphosphate made by acidulating the underflow fractions showed some increase in conversion over that of the untreated rock. The increase probably would not justify the cost of the treatment, which would involve an additional drying operation.

In the calcination treatment temperatures ranging from 500°F to 1800°F were used. The color and physical appearance of the rocks changed markedly, particularly at the higher temperatures. Also, the carbonate content of the rock was almost completely removed at the higher temperatures. Superphosphate made from the calcined rock, particularly rock calcined at temperatures above 700°F, had high moisture content, high free-acid content, and low conversion. This was probably due to low temperatures during mixing and curing as a result of the absence of carbonates, and to poor physical structure because of low gas evolution during curing.

Hammer-mill grinding and air separation using a Gruendler laboratory hammer mill and a Raymond air separator resulted in a coarse fraction, which contained the bulk of the material, and a fine fraction. The P_2O_5 content of the coarse fraction was higher than that of the fine fraction while the R_2O_3 content of the coarse fraction was much lower than that of the coarse fraction. Superphosphate made from the coarse fractions had conversions materially higher than those from the original rock. The increase in conversion was greater for the hanging-wall rock than for the foot-wall rock. Ball mill grinding was less effective than hammer mill grinding. The degree of beneficiation was such that this process appears feasible as a low cost method of improving the acidulation characteristics of the western rocks.

Froth flotation using a cationic collector to remove siliceous impurities was highly successful on deslimed Anaconda hanging-wall rock, and moderately successful on deslimed Anaconda foot-wall rock. The conversions of superphosphate made from hanging-wall rock treated by this process were considerably higher than those from the Florida land pebble rock used for comparison. Phosphorus pentoxide conversion of the foot-wall rock was improved to about the same degree by this process as by grinding and air separation. Savings in the acid required for acidulation of about 10 per cent for the hanging-wall rock and 5 per cent for the foot-wall rock were indicated.

A STUDY OF THE MINERAL REQUIREMENTS OF
RUMEN MICROORGANISMS¹Farris Everett Hubbert, Jr.²

Department of Animal Husbandry

This work was initiated to study the influence of the ash of an acid hydrolyzate of feather meal on *in vitro* cellulose digestion by rumen microorganisms, since this material had previously been shown to be a potent stimulator of cellulose digestion. It was hoped that if the ash of the hydrolyzate was active as a cellulose digestion stimulator, it would be possible to identify the active minerals. Another important phase of study was to determine the optimum concentrations for maximum *in vitro* cellulose digestion, as well as toxic levels of the various minerals used in the fermentation medium. A subsequent study of interrelationships of metal ions showing most importance in the *in vitro* work was believed essential for success in the study of mineral requirements. Finally, any minerals or combinations of minerals showing promise in artificial rumen studies were to be extended to lamb feeding trials to evaluate the *in vitro* results in terms of the intact ruminant animal.

A technique employing washed suspensions of rumen microorganisms obtained from fistulated steers was used in the *in vitro* study of cellulose digestion.

It was found that the ash fraction of hydrolyzed feather meal was responsible for a large portion of the stimulation of *in vitro* cellulose digestion attributed to the hydrolyzate. Sodium chloride produced during the neutralization of the acid hydrolyzate with sodium hydroxide was believed to be the active mineral.

The study of the requirement for various minerals for maximum *in vitro* cellulose digestion by rumen microorganisms indicated that potassium, sodium, sulfur, magnesium, and calcium should be included in the fermentation medium. The addition of manganese, iron, copper, cobalt, zinc, or boron to the fermentation medium did not increase *in vitro* cellulose digestion. Extremely low levels of copper, cobalt, zinc, and boron were found to depress cellulose digestion.

The study of the requirements for the alkali metal ions showed that potassium was essential for *in vitro* cellulose digestion by rumen microorganisms while sodium was not. An interrelationship was found between sodium and potassium in which the addition of sodium to the fermentation medium depressed cellulose digestion when potassium was present at a concentration of 50 micrograms per milliliter or less. However, when the potassium concentration was 100 micrograms or more per milliliter of fermentation medium the addition of sodium increased *in vitro* cellulose digestion. A ratio of 1:1 between sodium and potassium with a concentration of approximately 1000 micrograms of each mineral appeared to support maximum cellulose digestion. Rubidium was found capable of replacing approximately 50 per cent of the potassium requirement. However, lithium and cesium were inactive as replacements for the potassium requirement.

Fifty-four individually fed lambs were used in a factorial study of the influence of the addition of three levels of sodium chloride and three levels of potassium chloride to a low-ash basal ration. The basal ration was found to contain 0.01 per cent sodium, 0.39 per cent potassium, and 2.47 per cent ash.

¹Doctoral thesis number 1926, submitted June 6, 1957.

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The addition of 0.96 per cent potassium chloride or 1.65 per cent sodium chloride was found to increase daily gains approximately 0.25 pound per lamb, and feed consumption approximately 0.7 pound per day. The addition of 1.92 per cent potassium chloride or 3.33 per cent sodium chloride alone or in various combinations resulted in gains and feed consumption equal to or slightly lower than when the minerals were added at the lower levels.

EVALUATION OF CARBOHYDRATES FOR BABY PIGS¹

Donald Barton Hudman²

Department of Animal Husbandry

Seven experiments involving 841 baby pigs have been conducted to determine the ability of the baby pig to utilize various carbohydrates in dry diets with two basic types of protein, casein and soybean oil meal. The implication of various digestive carbohydrases has also been considered by including an assay of pancreatic tissue for amylase activity in baby pigs from one to 42 days of age.

The results show that as the levels of low heat, spray dried, dried skim-milk were increased from 0 to 20 to 40 per cent of the ration, there was a significant linear increase in one to three week gains and a significant improvement in feed efficiency. Although all pigs were fed the same starter from three to five weeks of age, there was a significant residual effect of the one to three week ration treatments as was reflected by significantly improving one to five week gains and feed efficiency with increasing levels of dried skimmilk.

In the same experiment there was no significant improvement in one to three week or one to five week gains or feed efficiency, by increasing the level of sugar from 15 to 25 to 35 per cent of the diet. This indicated that 15 per cent sugar was sufficient for maximum palatability.

Regardless of the sugar level fed, as the ration was changed from all dextrose to 1/2 dextrose-1/2 sucrose to all sucrose there was a significant linear improvement in one to three week gains, but this difference disappeared by five weeks of age.

There was no significant difference in 35 day weights of pigs weaned at different ages on to diets containing corn starch as the only carbohydrate. These pigs were weaned at three day intervals from three to 18 days of age. However, the pigs weaned to the starch diet at three days of age averaged 1.6 pounds lighter at 35 days of age than any of the other age groups. This work needs to be strengthened by further research.

Both the protein fraction, as represented by casein, and the carbohydrate fraction, as represented by lactose, were shown to contribute to the superior performance of 40 per cent dried skimmilk diets for baby pigs from one to five weeks of age. When both the lactose and casein were combined in the proportions found in a 40 per cent dried skimmilk diet, then added to the diet of baby pigs, the one to five week performance was comparable to that of pigs consuming a 40 per cent dried skimmilk diet.

In a comparison of 11 carbohydrate sources using a soybean oil meal diet for pigs from one to five weeks of age, lactose gave the best performance of

¹Doctoral thesis number 1818, submitted July 9, 1956.

Chairman of Committee, Damon Catron, Department of Animal Husbandry.

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M.S., *ibid.* Graduate Assistant, Agricultural Experiment Station.

any of the carbohydrates compared. Lactose produced significantly better gains than corn starch, cooked corn starch, amidex, corn syrup solids with a D.E. of 24, ground oat groats, and corn flakes.

In comparing the six different carbohydrates from the corn milling industry, classified on the basis of dextrose equivalent, there was a significant decrease in one to five week pig gains going from corn starch to cooked corn starch to amidex (D.E. 10). Then, there was a significant increase in gains as the products increased in D.E. from 10 to 24 to 42. The corn syrup solids with a D.E. of 42 gave comparable gains to sucrose and dextrose.

Ground yellow corn produced surprisingly good gains, while oat groats and corn flakes gave much poorer results.

A comparison of eight different carbohydrates was made with a casein protein diet for baby pigs from one to five weeks of age.

Sucrose produced statistically greater gains to five weeks of age than any of the carbohydrates tested. Lactose, dextrose, and dextrimaltose produced comparable gains and feed efficiencies and significantly greater gains than any of the other carbohydrates except corn starch. Ground yellow corn, ground oat groats, and amidex failed to give satisfactory gains when used as a carbohydrate source.

The analysis of pancreatic tissue of pigs at weekly intervals from one to 42 days of age for amylase activity was determined by a disc-plate method. The amylase activity per gram of dry pancreatic tissue increased from a very low level at one day of age to 14 days of age, decreased somewhat at 21 days of age and again increased rapidly to 28 days of age. After 28 days of age there was a levelling off in amylase activity. In considering amylase activity per pig there was an increase in amylase activity from one to 35 days of age.

The results of these investigations indicated that lactose and sucrose were the carbohydrates of choice for baby pigs from one to five weeks of age. The carbohydrate of choice was affected by the type of protein used in the diets.

OPTIMUM RESOURCE ALLOCATION FOR EROSION CONTROL FARMING ON IDA-MONONA SOILS¹

S.M. Aijaz Husain²

Department of Economics and Sociology

The primary objective of this study is to develop information that can serve as a guide for soil conservation farming systems on farms in the Ida-Monona soil area of western Iowa.

The recommended soil conservation practices restrict the cropping programs to soil-building rotations, so that the more popular exploitive type of cropping enterprises must be sacrificed. The time required to realize the benefits from conservation practices is generally too long to attract the farmer to erosion control. Moreover, the resource and product use problems common to the farm with conservation practices keep farmers from using improved soil management systems. The farmer can deal with the shortcomings of soil conservation methods by including new practices in an integrated type of farm planning. Thus, profit-maximizing plans conforming to

¹Doctoral thesis number 1895, submitted March 12, 1957. Chairman of Committee, Earl O. Heady, Department of Economics and Sociology.

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Graduate Assistant, Agricultural Experiment Station.

the restricted resources and conservation needs of individual farmers offer a direct and effective approach to accelerate adoption of erosion control farming. This study attempts to provide background information which may be used by farm specialists in their efforts to make the soil conservation farming system a profitable undertaking in the Ida-Monona soil area.

For the purpose of this study a "typical" farm of 280 acres was selected in the problematic area of western Iowa. The kind and quality of resources found on this farm were taken as a basis in determining the bench mark plans. Optimum plans were computed for \$6,000, \$12,000, \$18,000, \$24,000, and \$30,000 capital levels. The investment opportunities comprised five crop rotations, eight cattle feeding systems, one beef cow enterprise and two hog systems. Each of the five rotations was considered with two levels of fertilization. The pricing method used incorporates average historical relationships between corn price and prices of other items purchased or sold by farmers. These price relationships were adjusted to the 1955 corn price. The technique of linear programming was used to determine the optimum resource allocation for the various farm situations.

With \$6,000 in operating funds, maximum profit results from utilization of the relatively fertile fields, with 66 per cent of the funds invested in two-litter hogs. Some of the less productive cropland is not planted at this capital level because limited capital gives higher returns in livestock. The entire cropland area is planted when capital is increased to the \$12,000 level. The farm plan at this capital level includes cropping enterprises which maximize returns from various land resources or soil types. Remaining funds are invested in a two-litter hog program. When hog production is restricted to a maximum of 60 litters, some funds also are used for a deferred-fed calf enterprise. With the increase in funds beyond \$12,000, the calf enterprise expands up to the limit of feed grain production. Thereafter, beef cows substitute the calves until forage production restricts their expansion.

Although an increase in investment, from a very limited amount of capital to the unlimited level, increases the net returns at a decreasing rate, the earnings on the added funds are sufficiently high to merit use of borrowed funds. Farmers with extremely limited capital resources would receive high returns on borrowed funds.

The cropping program for farmers desiring to expand hog output conforming to their capital and land resources includes CCOM₂ on the more productive soils. Remaining cropland area is used in accordance with the profitability of simultaneous crop and two-litter hog production up to the \$12,000 level. Beyond this capital level, feed grain production is gradually maximized. When feed grain production limits the expansion of two-litter hogs, the one-litter hogs and then the beef cows profitably employ the increased capital supply until forage production becomes restrictive.

When buildings must be constructed for livestock production, all cropland is cultivated prior to investment in livestock enterprise. With the increase in capital resource, the cropping and livestock enterprises expand in the same manner as in the situation where building investment is not required. The necessity of investing in livestock buildings lowers farm income for the first two years when \$12,000 and \$18,000 capital levels are assumed and only for one year when \$24,000 of capital are available. At the former two levels, the sacrifice in income is considerably reduced in the second year of operation because of building investments of the first year. Thus, at these capital levels the lack of livestock buildings should not be a serious handicap to soil conservation farming methods.

The farmer on a 280-acre farm with "typical" labor supplies requires 203 man-hours of additional labor to achieve maximum returns from an investment of \$12,000. Although labor requirements increase as more capital is invested in the farm plan, the family labor supply can be economically supplemented by hiring "extra" labor. Therefore, farmers should fully explore the possibilities of hiring additional labor when family labor limits the expansion

of farming activities. As in the situation with unlimited labor, the "optimum" enterprises are not affected by the presence or absence of livestock buildings. The farm income at each capital level is temporarily reduced because of the required building investments.

If hog prices decline by 20 per cent (prices of other resources and products remaining unchanged), the long-term plan with limited labor supply will yield a 35.3 per cent net return on an investment of \$12,000. The optimum allocation of this investment with the reduced hog prices improves the net return by only 3.2 per cent. At the \$18,000 capital level, the gain in net income with a short-term optimum plan conforming to the new price relationships is only 0.8 per cent. These results indicate the over-all stability of the long-term, profit-maximizing plans up to a fall of 20 per cent in hog prices.

All these plans may be used according to the appropriate farm situation to allow farmers to use soil conservation practices and at the same time realize a maximum profit from a farm enterprise adapted to these practices.

FACTORS ASSOCIATED WITH FATAL ACCIDENTS OF RURAL RESIDENTS OF IOWA, 1947 TO 1953

Carlton Egbert Johnson²

Department of Vocational Education

The study was undertaken to determine factors associated with fatal accidents of rural residents of Iowa during 1947 to 1953, inclusive, using death certificates as a source of information. Rural residents, as the term is used in this study, included all inhabitants of unincorporated places. The term also included all farmers, retired farmers, farm laborers, or family members of these persons living in incorporated places.

More specifically the purpose of the study included the following:

1. To determine relationships of age, sex, marital status, and occupation to fatal accidents.
2. To analyze location as a factor in fatal accidents.
3. To summarize data concerning the time that accidents occurred in terms of month, day of week, special holiday, and the hour.
4. To summarize data concerning the vehicle, object, or element involved in fatal accidents.
5. To determine if different types of farming areas showed variations in numbers of tractor fatalities.
6. To summarize the data concerning nature of the accidents.
7. To summarize the data concerning the nature of the injuries.
8. To suggest implications for safety education based on the findings of the study.

There were 3599 accidental deaths to rural residents of Iowa, as defined in this study, during the seven-year period, 1947 to 1953. It was found that persons in the age group from birth through 4 years of age had the largest number of accidental deaths of any group, but the rate of death per 100,000 for persons in this age group was only 46.4. The lowest rate of death for all age groups, 20.5, was reported for the age group 5 to 9. The rates 57.6 for the age group 15 to 19, and 57.4 for the age group 20 to 24 were the highest

¹Doctoral thesis number 1840, submitted August 15, 1956. Chairman of Committee, John B. McClelland, Department of Vocational Education.

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among the age groups from 1 to 60 years of age. The rate of accidental death increased rapidly for persons in the age groups over 65.

When the victims of fatal accidents were classified according to occupation it was found that 1214, or 33.7 per cent, of the 3599 fatal accidents had occurred to farmers, which is twice as many as for any other occupational group included in the study. Retired farmers were next highest in the occupational classification with 550 cases, or 15.3 per cent.

Of the 3599 fatal accidents investigated, 39.2 per cent occurred on the street or highway, 27.5 per cent occurred in the home area, and 21.7 per cent occurred on the farm. The home area included the area within the house and the yard around the house.

Of all fatal accidents to rural residents of Iowa, 79.3 per cent occurred to males. More than two thirds of the fatalities of male workers occurred when they were not at work. When all males, ages 15 to 64 inclusive, who were classified as farmers, farm laborers, and pupils were grouped together, single males were found to have had almost 3 times as many fatal accidents on the street or highway as on the farm. Married males, ages 15 to 64 inclusive, had about the same number of fatalities on the farm as on the street or highway. Single and married males, ages 15 to 64, each had about the same total number of fatalities. However, single males had a fatality rate per 100,000 nearly twice as high as the rate for married male workers.

More farm accidents were reported during the late spring, summer, and early fall months than during the late fall and winter months. Street and highway accidents were most numerous during the summer and fall months. More accidents in the home area occurred during the winter months than occurred during the other months.

More of the fatal accidents of rural residents occurred on Friday and Saturday than on other days of the week. Morning accident figures were highest on Saturday and Sunday. An average of 1.51 fatal accidents occurred on special holidays as compared to 1.42 accidents per day for all other days.

Persons in the age groups from birth to 14 years of age had nearly one half of all of their afternoon fatalities during the hours from 4 to 6 p.m. For the age groups 15 to 64, afternoon-work-hour accidents occurred in the greatest numbers between 3 and 4 p.m., but there were nearly as many from 4 to 5 and from 5 to 6 p.m. Of the morning-work-hour accidents which involved persons 15 to 64 years of age, 51 per cent occurred during the two hours before noon.

When fatal accidents of rural residents were classified according to the vehicle, object, or element involved, motor vehicles were found to account for 35.9 per cent of all fatal accidents; buildings ranked second with 18.3 per cent, and tractors third with 8.4 per cent. Of the 302 tractor fatalities, 36.4 per cent occurred on the street or highway and 61.5 per cent on the farm. In May and October there were more than five times as many tractor fatalities on the farm as on the street or highway. It should be noted that tractors were doubtless operated many more hours during these months than during some other months of the year. The rate of fatal tractor accidents per hour of use was not determined. The lowest fatal accident rate with tractors on a basis of the number of tractors per county was reported in counties having land with the least slope.

Reports concerning the nature of the accidents showed that 60.9 per cent of the tractor accidents involved overturning; 52.6 per cent of the automobile fatalities resulted from collision; and 90.6 per cent of the accidents in buildings were due to falls. Very little information was provided in death certificates concerning factors which contributed to fatal accidents.

BINDING ENERGIES OF THE LIGHT HYPERFRAGMENTS¹James Thomas Jones, Jr.²

Department of Physics

During the last decade, many so-called fundamental particles have been discovered (1). A neutral particle of particular interest in the present work is the Λ^0 , which has a rest mass of about 2181 electron masses and a mean lifetime of about 4×10^{-10} sec. Since the delayed disintegration of a heavy nuclear fragment was first reported by Danysz and Pniewski (2), many events have been observed which establish the fact that a Λ^0 together with a number of nucleons can form systems which are stable for times of the order of lifetime of the free Λ^0 . Such bound systems are called hyperfragments. There is tentative evidence (3, 4) that "strange" particles other than the Λ^0 may also form bound systems with nucleons; however, such systems are not considered here.

The purpose of the present work is to determine the parameters of a phenomenological potential of the Λ^0 -nucleon interaction (assumed to arise predominantly from the virtual exchange of heavy mesons) by fitting them to the observed binding energies of the light hyperfragments. To this end, variational calculations are carried out for the hyperfragments with mass numbers less than or equal to five.

The calculations indicate that the Λ^0 -nucleon interaction is strongly spin-dependent; that the ground state of the hypertriton ($\Lambda^0 + H^2$) is a spin quartet; and that the total spin of hyperhydrogen-4 ($\Lambda^0 + H^3$), as well as hyperhelium-4 is 1. However, if the inaccuracies of the calculations are such that the total energies of these hyperfragments are in error by five per cent or more, one cannot exclude an alternative possibility that the ground state of the hypertriton is a spin doublet (in an i-spin singlet state) and that the spin of the four-particle hyperfragments is 0. In either case, it is likely that neither hyperhelium-3 ($\Lambda^0 + 2p$) nor the hypertrineutron ($\Lambda^0 + 2n$) would be bound.

In reaching these conclusions the chief assumptions which have been made are: (a) the hyperdeuteron ($\Lambda^0 + p$) is not bound; (b) the spin of the Λ^0 is $1/2$; (c) the Λ^0 -nucleon interaction arising from the virtual exchange of heavy mesons may be represented by the assumed phenomenological potential (any possible pion admixture resulting from the virtual exchange of at least two pions between the Λ^0 and nucleon being neglected); (d) all but the principal S-states of the hyperfragments with mass numbers less than or equal to five may be neglected, the nucleon-nucleon interaction being represented by the central Yukawa interaction. The last two assumptions are rather severe. There is, a priori, no justification for assumption (c), and certainly none for the last assumption. However, the results obtained here, together with those on light nuclei, indicate that before one introduces a phenomenological potential for the pion admixture, with the intention of obtaining an approximate value of its strength, the tensor interaction between nucleons must at least not be neglected.

The Λ^0 -nucleon interaction is assumed to be represented by the potential,³

¹Doctoral thesis number 1838, submitted August 11, 1956.

Chairman of Committee, Joseph M. Keller, Department of Physics.

²B.S., Southern Methodist University, Dallas, Texas. M.S., Iowa State College, Ames. Research Assistant, Ames Laboratory of the Atomic Energy Commission.

³Because of the trial wave functions used in the variational calculations for the hyperfragments with mass numbers less than or equal to five are assumed to be symmetric with respect to the interchange of the positions of any pair of particles, a space exchange operator is not explicitly displayed in V_{12} .

$$V_{12} = (1 + a_0 \underline{\sigma}_1 \cdot \underline{\sigma}_2) K(r_{12}),$$

where r_{12} is the distance between the Λ^0 and the nucleon, σ is the Pauli spin vector, and a_0 is a numerical parameter. The space part of the interaction potential is assumed to have a Yukawa radial dependence,¹

$$K(r_{12}) = -K_0(\beta_0 r_{12})^{-1} \exp(-\beta_0 r_{12}), \quad (K_0 > 0)$$

where K_0 is the strength and β_0 is the inverse of the range of the Λ^0 -nucleon interaction. Since the interaction is assumed to arise from the virtual exchange of heavy mesons, β_0 should approximately be equal to the inverse of the heavy meson Compton wave length.

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¹The possibility of obtaining a reasonable value for the calculated total binding energy of hyperhelium-5 is excluded if $K(r_{12})$ is assumed to be repulsive (i.e., $K_0 < 0$).

AN INVESTIGATION OF THE MALE GENITALIA AS TAXONOMIC CHARACTERS IN THE MIRIDAE (HEMIPTERA)¹

Leonard Alexander Kelton²

Department of Zoology and Entomology

A study was made of nearly 300 species from approximately 120 genera representing 17 tribes of the six subfamilies of the Miridae. The first important aspect of the problem was: (1) to establish the structural pattern of the male genitalia within the genera of the subfamilies; (2) to observe the stability or variability in the basic pattern of these structures; (3) to determine whether these structures could be used as indicators of phylogenetic relationship between genera and higher categories; and (4) to determine whether these structures could be used in the over-all classification of the Miridae.

The second aspect of the problem was to determine whether the male genitalia or the tarsal arolia were more resistant to change when the external appearance of the species assumed extreme modifications from the generalized forms of the group. To the present time tarsal claw characteristics have been considered to be the best characters for dividing the family into subfamilies and tribes.

The two structures of the male genitalia considered in this study were the vesica and the claspers. Considerable more emphasis was given to the vesica since it appeared to possess a stable structural pattern of extreme taxonomic

¹Doctoral thesis number 1932, submitted June 7, 1957. Chairman of Committee, H.H. Knight, Department of Zoology and Entomology.

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and phylogenetic value that could be employed in establishing generic and tribal relationships of the family.

The regions of the vesica found to be of considerable value were the design of the rim of the gonopore, the ductus seminis, and the processus vesicae. The phallosome appeared to be of some value in the identification of certain groups in the family.

The study indicated that the arolia and the claws must be used with considerable caution when separating subfamilies. The genital structures of the species examined appear to indicate the relationships to their allies, even though the external morphology of the species may show no such relationship. In several instances the vesica and the claspers suggested that the present taxonomic placement of a number of genera based on their arolia are not in accord with the evidence offered by the genital structures studied.

CHARACTERISTICS OF THE SOLID STATE TRANSFORMATIONS IN URANIUM¹

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The thermal expansion of uranium and the nature of allotropic transformation processes in uranium are of obvious interest in predicting or understanding the effects of thermal cycling on components fabricated of uranium such as nuclear fuel elements. Quite apart from this possible immediate practical interest is the theoretical interest in the transformation processes themselves. The purpose of the investigation reported was to determine the temperature dependence of the lattice parameters of uranium from room temperature to the melting point and to provide experimental data on the general characteristics and kinetics of the allotropic transformations in uranium. Toward this end high-temperature x-ray diffraction, electrical resistance, and sonic experimental techniques were employed. The data presented are interpreted in terms of the known physical, mechanical, and structural properties of the metal and are intended as a contribution toward the complete experimental and theoretical description of the allotropic transformation processes in pure uranium.

Resistance effects observed accompanying the alpha-beta transformation in high purity uranium indicate a certain degree of reversibility in the orientation of a given grain on thermal cycling through both transformations. The effect on the alpha-phase thermal twinning temperature, on the resistance of newly-formed alpha, and on the transformation temperatures resulting from rapid thermal cycling of uranium through both allotropic transformations is interpreted to indicate progressive lattice hardening.

It has been shown that the allotropic transformations in uranium proceed isothermally, but that the extent of isothermal transformation is a function of temperature over a definite temperature range. The isothermal transformation initially involves bursts of transformation activity and proceeds in its later stages very slowly to an apparent end of transformation.

The lattice parameters of high purity uranium from room temperature to the melting point have been experimentally determined. The crystallographic

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features of the alpha-beta transformation have been discussed in terms of the lattice parameters of the two phases and the volume change at the transformation temperature. The habit plane calculated is close to the $(2\bar{1}1)$ beta plane. This habit plane has not been experimentally observed.

From the evidence presented it is concluded that the allotropic transformations in uranium proceed by the nucleation and slow growth of coherent nuclei. The features of the transformations are closely similar to those of typical martensitic reactions, except for the kinetic features. Arguments have been proposed to explain these nontypical kinetic features.

SEPARATION OF NIOBIUM AND TANTALUM BY LIQUID EXTRACTION¹

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Niobium, also known as columbium, is one of the new industrial metals likely to play an important role in industrial processing in the near future. Its high melting point (4376°F) and low cross section for neutron absorption (1.1 barns) makes it of special interest to the Atomic Energy Commission. Since tantalum, which invariably accompanies niobium in its ores, has a somewhat higher cross section for neutron absorption (21 barns) there is considerable interest in developing an industrial process for producing tantalum-free niobium. Tantalum itself is a valuable metal because of its high melting point (5160°F) and its resistance to most corrosive chemicals.

The purpose of this research was to find an economical method of producing a niobium oxide product containing as little tantalum and other impurities as possible starting with a typical niobium-rich ore or concentrate. The process selected as a result of the research consisted of the following processing steps: (1) Digestion of the ore or concentrate with hydrofluoric acid. (2) Extraction of niobium and tantalum from the digested mass with an organic solvent such as methyl isobutyl ketone. (3) Separation of tantalum and niobium by continuous countercurrent multistage extraction using an organic solvent and an aqueous scrubbing solvent. (4) separation of niobium from other impurities by a second solvent extraction step using an organic solvent. (5) Stripping of the niobium and tantalum from their solvents and regeneration of solvents.

The process as outlined above was studied on a small scale and demonstrated on a somewhat larger scale so that a more accurate cost estimate could be made. Several pounds of niobium oxide containing less than 700 ppm of tantalum oxide were produced. Several pounds of tantalum oxide containing less than 100 ppm of niobium oxide were produced. Both purity values were the limit of detection for the spectrographic methods employed.

Preliminary cost estimates were made for production of purified niobium and tantalum oxides from an ore concentrate assaying 63 per cent niobium oxide and 7 per cent tantalum oxide. The basis chosen was a plant producing 300,000 pounds of total oxides per year or 270,000 pounds niobium oxide and 30,000 pounds tantalum oxide. Estimated chemical and total operating costs for one pound of either tantalum or niobium oxide were \$1.89 and \$2.80.

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Chairman of Committee, Morton Smutz, Department of Chemical Engineering.

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PURIFICATION AND PROPERTIES OF SPLENIC DESOXYRIBONUCLEASE¹James Frederick Koerner²

Department of Chemistry

A procedure was developed for the extensive purification of splenic desoxyribonuclease (DNase). The enzyme is initially adsorbed onto the insoluble components in a homogenate of the spleen of cattle in dilute pH 4.5 acetate buffer. Inactive, highly soluble proteins are removed from this homogenate by washing with dilute buffers. The DNase is then eluted from less soluble material with an improvement of specific activity of about fifty-fold. This eluate is then subjected to a heat fractionation and ethanol fractionation which increase the specific activity of the solution another forty-fold. A contaminating acid phosphatase is then completely separated from the DNase by means of a gradient elution chromatography on a Celite column. This chromatogram also separates the diesterase activity detected with bis(p-nitrophenyl)phosphate into two fractions, one still accompanying the DNase.

The DNase requires a solution of ionic strength of approximately 0.2 from monovalent anions and cations for optimum activity. Divalent magnesium also activates to a lesser extent. The optimum pH is 4.5.

The DNase preparation is very stable when stored in solution in the cold room. DNase solutions under acidic conditions are resistant to heating to 60°C. Alkaline solutions are less stable. Solutions with a pH greater than 8.5 are unstable at room temperature.

The rate of release of monoesterified phosphate from highly polymerized thymic desocyrbonucleic acid (DNA) by the action of the DNase was measured by the method of Sinsheimer. This method utilizes the hydrolysis of the monoesterified phosphate to inorganic phosphate by means of prostatic phosphatase followed by a determination of the inorganic phosphate. The DNase degradation was found to proceed in three stages of greatly differing rates. An initial rapid primary degradation continues until one-tenth of the total phosphate has become monoesterified. A secondary degradation of approximately one-thirtieth the rate of the primary continues until two-tenths of the total phosphate has become monoesterified. After this, a still slower tertiary degradation continues to depolymerize the polynucleotides. Attempts to fractionate the preparation into two activities, one causing the primary degradation and the other causing the secondary degradation, were unsuccessful. For this reason, both activities must be tentatively considered to be due to one DNase.

Rattlesnake venom phosphodiesterase has been purified by a new acetone fractionation procedure which yields a preparation of high potency and free of 5-nucleotidase. The polynucleotides from a primary splenic DNase digest were degraded with prostatic phosphatase followed by degradation with this diesterase. This digest yielded 10 per cent nucleosides and 90 per cent mononucleotides. Degradation of the DNase polynucleotides with the diesterase alone proceeded very slowly but eventually yielded a digest containing 10 per cent nucleosides, 80 per cent mononucleotides, somewhat less than 10 per cent of substances tentatively identified as nucleoside diphosphates, and a few per cent of unidentified polynucleotides. These results indicate that the polynucleotides of a splenic DNase digest have the monoesterified phosphate in the 3' position on the desoxyribose. This is in contrast to the 5' monoesterified phosphate of pancreatic DNase polynucleotides.

The fact that the diesterase digest nucleoside and nucleoside diphosphate

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Chairman of Committee, Robert L. Sinsheimer, Department of Chemistry.

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fractions both contain all four of the major bases in thymic DNA indicates that the splenic DNase shows no specific preference for the bases on the nucleotide residues adjacent to either side of the 5' phosphodiester bonds hydrolyzed. No explanation has been devised for the great decrease of rate of degradation after one-tenth of the total 5' phosphodiester bonds are hydrolyzed.

The products of the secondary and tertiary degradation cannot be studied by the same method used for the primary degradation, since some of the polynucleotides formed at these stages are resistant to the venom diesterase. The evidence available suggests that they also are 3' polynucleotides plus some nucleoside 3'-phosphates.

THE EFFECT OF SUBSTITUENTS ON THE INFRARED SPECTRA OF AROMATIC COMPOUNDS¹

Robert David Kross²

Department of Chemistry

The mechanical and electronic effects of substituent groups on aromatic systems are manifest in the infrared spectra of the aromatic compounds. Inductive, resonance, and steric interactions constitute the three main areas of intramolecular influence. By studying specific infrared spectral regions of certain parent compounds, the various effects can be examined and qualitatively and quantitatively determined. The particular areas investigated were: a) the nitro valence vibrations of variously substituted nitrobenzenes; b) the aromatic C-H out-of-plane and in-plane bending vibrations; c) the C≡N band intensity in substituted benzonitriles; d) the characteristic vibrations of picric acid when complexes with other aromatic compounds; e) the infrared dichroism of molecular complexes; and f) the dichroism of the 5-6μ region in the spectra of substituted benzenes. Summaries of the separate sections which comprise the dissertation are as follows:

The effect of substituents on the nitro valence vibrations in substituted nitrobenzenes. The characteristic nitro asymmetric and symmetric frequencies of substituted nitrobenzenes are correlated with structure related parameters which are sensitive to the electronic effect of the substituent on the nitrobenzene nucleus. It is shown that molecular dipole moments, as well as Hammett sigma constants for the para groups, yield straight line curves when plotted against the corresponding asymmetric frequency of para-substituted nitrobenzenes. A plot of nitro asymmetric vs symmetric frequency in the latter compounds yields a discontinuous curve, the reasons for which are discussed. In meta-substituted nitrobenzenes the asymmetric nitro frequencies also correlate well with the appropriate Hammett sigma constants. In these compounds, the difference between the asymmetric frequencies obtained from samples in the solution and solid phase yield a straight line curve when plotted against the corresponding melting points of the compounds. This is related to the intermolecular forces stabilizing the crystal of the nitro compound. The symmetric nitro stretching vibration, in ortho-substituted nitrobenzenes, is apparently more sensitive to the mechanical perturbations and local field effects of the adjacent group than is the asymmetric vibration. Evidence is presented which places the C-NO₂ stretching vibration in the 1300 cm⁻¹ region. For the three types of substitution, the average nitro

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frequencies and their average deviations are in accord with expectations based on the various perturbations imposed by the substituents.

The effect of substituents on the C-H out-of-plane bending vibrations in substituted benzenes. In certain monosubstituted and para-disubstituted benzenes the frequency of one of the C-H out-of-plane bending vibrations falls above the characteristic frequency range assigned to the vibration. A property common to all of the substituents which cause this positive shift in frequency is that they are electrophilic in nature, i.e., they tend to deplete the aromatic nucleus of π -electronic charge. These experimental observations are consistent with the theory of orbital following during molecular vibrations. The depletion of π -electron density of the aromatic nucleus by electrophilic substituents leads to a decreased ability of the carbon bonding orbitals to follow the out-of-plane movement of the hydrogen atoms. This results in higher bending frequencies because the vibrations occur with greater difficulty as orbital overlap decreases. Applications of this theory to other spectral anomalies are also discussed.

The effect of substituents on the 1045-1185 cm^{-1} vibration in monosubstituted benzenes. In monosubstituted benzenes of the type $(\text{phenyl})_n\text{M}$, where n is the valence of the substituent element M, the frequency of the 1045-1185 cm^{-1} vibration is directly related to the partial ionic character of the $\text{C}_{\text{ar}}\text{-M}$ bond. Using the square of the electronegativity of the substituent as a measure of the bond polarity, a plot is presented which relates this parameter to the corresponding frequency. From the four straight-line curves obtained for group IVB, VB, VIB, and VIIIB elements, an expression is derived equating electronegativity with the observed frequency. Electronegativity values calculated from this equation compare favorably with accepted values.

The effect of substituents on the $\text{C}\equiv\text{N}$ band intensity in substituted benzonitriles. Using the absolute nitrile band intensities found in the literature, and assuming such factors as band shape and effective slit width to be constant, the absolute intensities were related to peak intensities through an arbitrary constant. The arbitrary constant was then applied to the peak intensities of three other nitriles to determine their absolute intensities. The smooth curve then obtained by plotting the absolute intensities against the Hammett sigma constants of the second substituent on the aromatic ring indicates that the intensity is a function of the electronic perturbation of that group.

Regularities in the infrared spectra of picric acid molecular complexes. The infrared spectra of forty picric acid molecular complexes show that the nitro asymmetric stretching and the out-of-plane C-H bending vibrations of the picric acid component are sensitive to complex formation. The frequencies of these vibrations can be correlated with the type of complex formed, i.e., π - π or n - π charge transfer. Many of the complexes were found to contain an additional asymmetric nitro stretching vibration. The appearance of this additional band and independent crystallographic evidence suggest that these particular complexes contain an additional localized intermolecular interaction.

Infrared dichroism studies of some molecular complexes. The results of a study on the polarized infrared spectra of the hexamethylbenzene-picryl chloride, anthracene-symtrinitrobenzene, and *p, p'*-dinitrodiphenyl-*p*-hydroxydiphenyl molecular compounds show agreement with published X-ray crystal structures. On the basis of the observed dichroism, molecular orientations are suggested for the complexes of picric acid with β -methylnaphthalene and piperidine.

The infrared dichroism of the 5-6 μ region in the spectra of substituted benzenes with relation to the type of substitution. The dichroism of the 5-6 μ region in the spectra of six substituted benzenes lends support to the assignment of the bands in this region to summation bands and overtones of C-H out-of-plane bending fundamentals. Additional confirmation resides in the possibility of adding the characteristic summation patterns of certain basic groups to obtain patterns characteristic of other types of substitution.

SOME ECOLOGICAL RELATIONSHIPS OF THE GIZZARD SHAD,
DOROSOMA CEPEDIANUM (LE SUEUR),
IN A DREDGED PRAIRIE LAKE¹

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Department of Zoology and Entomology

The gizzard shad, *Dorosoma cepedianum* (LeSueur), has attained widespread recognition as a nuisance fish in recent years. Irruptions of the gizzard shad in North Twin Lake, Iowa in 1954 and 1955 provided a good opportunity to investigate some of the basic ecological relationships of this species and at the same time supplement what little is known of its over-all biology. North Twin Lake is a shallow, highly productive (eutrophic), prairie lake containing good populations of desirable game and pan fish such as yellow bass, walleyes, and black bullheads.

Relationships between plankton abundance and plankton consumption by shad were determined by sampling both plankton and fish concomitantly at various times during the period June-October, 1955. All young-of-the-year and yearling shad (as well as young game and pan fishes) were sampled by seining. All larger specimens (including game fishes for shad utilization studies) were taken by gill-netting. Plankton samples were analyzed numerically and volumetrically employing the centrifuge method of concentration and the Sedgwick-Rafter cell method of enumeration. Fish digestive tract contents were also analyzed from numerical and volumetric standpoint.

A separate treatment of plankton samples obtained during 1955 together with several others secured during 1951-54 and 1956 revealed the presence of at least 230 phytoplankton and 119 zooplankton species and varieties in North Twin Lake. The green algae were best represented species-wise among the phytoplankton and rotifers among the zooplankton. Quantitative analyses of the 1955 plankton samples disclosed that, on the average, diatoms comprised the largest segment of the plankton with blue-green algae a close second. The 1955 phytoplankton-zooplankton ratio was found to be about 5.4:1.

A calculated index (the compound quotient devised by G. Nygaard) to the trophic status of North Twin Lake based upon the numbers of species comprising certain phytoplankton taxa was within the limits expected considering the highly eutrophic nature of this body of water.

Analyses of the digestive tract contents of 60 gizzard shad revealed that 76 per cent of the phytoplankton and 60 per cent of the zooplankton species and varieties known to exist in North Twin Lake were consumed in varying amounts during the period June-October, 1955. Zooplankton, especially crustaceans, were principal shad foods in spring and early summer. Phytoplankton were primary foods during the mid-summer and fall months. Planktonic Crustacea, especially *Daphnia longispina* and *D. pulex*, seemed to be essential as shad foods during early developmental stages following hatching.

A fair degree of relationship existed between the amounts of green algae and diatoms consumed by young-of-the-year shad and the proportions of the same forms in the environment. A definite selectiveness on the part of the yearling shad was noted for green algae. A good correlation appeared to exist between the amounts of rotifers in the environment and the proportion that these forms comprised in shad digestive tract contents. Crustaceans were definitely a select food item of young-of-the-year shad while older individuals seemed to utilize them somewhat in proportion to their relative abundance.

¹Doctoral thesis number 1836, submitted August 10, 1956. Chairman of Committee, Kenneth D. Carlander, Department of Zoology and Entomology.

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Blue-green algae were not consumed in proportion to their relative abundance by North Twin Lake shad in 1955. Microcystis aeruginosa, important from the standpoint that it often develops to objectionable proportions, appeared to be selected as a food item since it was frequently present in significant amounts in shad digestive tracts but not in the plankton. In contrast, Aphanocapsa delicatissima, the most abundant North Twin Lake plankter during the mid-summer, only comprised relatively small portions of shad digestive tract contents. Although there appeared to be a good correlation between increases in shad abundance and diminution of undesirable blue-greens (especially Microcystis aeruginosa and Anabaena spiroides), the role of the shad as a possible control of these organisms was questioned because of evidence that these and other blue-greens may not be readily digested by plankton-consuming fishes such as the shad.

As regards the general feeding habits of the gizzard shad, the fact was verified that whether accidentally or purposively, individuals of this species are capable of retaining relatively minute organisms for consumption. Many of the plankton species commonly encountered in shad digestive tract contents were no larger than 20 μ in greatest dimension. Included here were species of Achnanthes, Cyclotella, Golenkinia, Oocystis, Scenedesmus, Tetradron, Merismopedia, Euglena, Glenodinium, and Phacus.

Examination of stomach contents of various game and pan fishes disclosed that crustacean plankters, primarily Bosmina, Daphnia, Moina, Leydigia, Cyclops, and Diaptomus were important foods of newly hatched specimens. Since several of these forms (especially Daphnia) also constituted primary foods of newly hatched shad, a possible competitive relationship between the abundant shad and the less abundant game fishes during initial growth stages was suggested.

Examination of sub-adult and adult game fish revealed that gizzard shad were by far the most important forage species in North Twin Lake during 1954 and 1955. Young-of-the-year yellow bass were next in importance but were utilized in comparatively small amounts. Both yellow bass and walleyes commonly utilized yearling shad during the 1955 summer although the ratio of yearling to young-of-the-year shad consumed by walleyes was somewhat greater than the same ratio observed for the yellow bass. The fact that North Twin Lake shad are vulnerable to predation over a longer period of time than are shad in several midwestern and most southern waters may be an important factor in regulating their populations. It was suggested that any competitive effects the shad may have on desirable species, especially during early life stages, is offset or balanced by the forage the shad provide for the latter during later life.

MOUTH SIZE OF LARGEMOUTH BASS IN RELATIONSHIP TO SIZE OF FORAGE FISHES¹

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The purpose of this research was to determine the size of various forage fishes a largemouth bass, *Micropterus salmoides* Lac., can swallow and to derive prediction equations for estimating these size relationships. The relationship between mouth width and total length of largemouth bass was determined from 1377 individuals ranging in size from 31 to 595 millimeters in total length. The mouth width measurement was made externally between the posterior margins of the preopercula with the opercular flaps in the closed position. There was no single linear equation determined from either the actual or logarithmic values of measurements which would give satisfactory estimates of mouth widths over the entire range of total lengths. Rather, linear equations which covered only 100 millimeter intervals of total length had to be used to give satisfactory estimates of mouth widths. Equally accurate estimates of mouth widths, determined for 100 millimeter intervals of total lengths, were obtained from either actual or logarithmic values of measurements.

The total length ranges of forage fishes for which the relationships between maximum depth of body and total length were determined included the following: bluegill, *Lepomis macrochirus* Raf., 14-235 mm; redear sunfish, *L. microlophus* Gunther, 75-220 mm; green sunfish, *L. cyanellus* Raf., 14-181 mm; golden shiner, *Notemigonus crysoleucas* (Mitchill), 48-215 mm; and goldfish, *Carassius auratus* (Lin.), 35-130 mm. Single linear regression equations, covering the full range of total lengths, were calculated for each of these species of forage fish. Equal accuracy of prediction was obtained using either actual or logarithmic values of measurements.

Dissection suggested that the width between the cleithrum bones limits the size of fish a bass can swallow. This width between the cleithrum bones was found to be the same as the mouth width measurement previously described. It was postulated that a largemouth bass of a given total length could swallow a forage fish whose maximum depth of body was equal to the mouth width of the bass. However, feeding experiments indicated that bass would eat forage fish with maximum depths somewhat greater than the mouth width.

The estimated total lengths of the various forage fishes largemouth bass of given total lengths can swallow were computed and tabulated. The equations used for estimating the mouth widths of largemouth bass were as follows:

Total length		
less than 100 mm	$M = 1.88 + 0.0775 L$	$s = 0.68$
100 - 199 mm	$M = -0.98 + 0.1043 L$	$s = 2.13$
200 - 299 mm	$M = -7.03 + 0.1358 L$	$s = 3.21$
300 - 399 mm	$M = -2.84 + 0.1212 L$	$s = 4.39$
400 - 499 mm	$M = -19.99 + 0.1755 L$	$s = 5.47$
500 - 595 mm	$M = -50.77 + 0.2405 L$	$s = 6.42$

The equations for estimating the total lengths of forage fishes from maximum depth of body were as follows:

¹Doctoral thesis number 1852, submitted November 28, 1956. Chairman of Committee, Kenneth D. Carlander, Department of Zoology and Entomology.

²B.S., Alabama Polytechnic Institute, Auburn. M.S., *ibid*.
Graduate Assistant, Industrial Science Research Institute.

bluegills	$L = 19.10 + 2.3925 D$	$s = 11.75$
redecor sunfish	$L = 6.06 + 2.8917 D$	$s = 7.38$
green sunfish	$L = 11.70 + 2.6859 D$	$s = 4.96$
golden shiner	$L = 18.30 + 3.8876 D$	$s = 7.19$
goldfish	$L = 22.09 + 2.5992 D$	$s = 10.29$

The practical application of the relationships between mouth widths of bass and maximum depths of body of forage fishes was demonstrated using the fish population data obtained upon draining a 1.4 acre pond. It was shown that a more accurate Y/C ratio for a pond population, where the bass is the principal or only piscivorous species present, was possible since the actual size of forage fish available as food for the bass could be determined. It was also shown that cumulative and proportional Y/C ratios for each inch-group of bass could be calculated. It was suggested that such calculated Y/C ratios might aid considerably in determining the relationships within a fish population, particularly as concerns the "balance" within the population. It was also proposed that further applications of this relationship will be found when sufficiently detailed data, obtained from numerous populations of fish, are available for study.

EFFECTS OF CHEMICAL SEED TREATMENTS ON WIREWORM ACTIVITIES¹

William Henry Long²

Department of Zoology and Entomology

The studies reported in this thesis were carried out to compare the relative merits of several chlorinated hydrocarbon insecticides as seed treatments on corn to protect it against wireworms. Comparisons were also made of different rates of insecticide application, and of different diluents in the insecticide formulations. Certain water-soluble diluents were used in the early experiments with the hope that a formulation might be developed that would improve plantability and help solve the problem of disposing of excess treated seed corn for other uses. After some of the water-soluble materials were eliminated from further consideration, vermiculite was added to the list of diluents to be studied. It seemed possible that the same dosage of a given insecticide might give different plant and insect responses when formulated in different diluents.

Laboratory and field experiments were carried out to determine the effects of the various insecticide treatments on germination and seedling development. Obviously a phytotoxic seed treatment is of less value and interest than a non-phytotoxic treatment, although their abilities to kill wireworms and protect seeds are equal. Several experiments were carried out in which wireworms were exposed to treated seeds in glass jars to obtain quantitative data on the insecticidal effects of the treatments. Studies of a more qualitative nature were carried out on wireworm orientation reactions to chemical seed treatments. Most of these involved the use of cobalt-60 for tagging the wireworms (*Melanotus communis* Gyll.) so that their movements could be followed in crocks of soil containing treated seeds. It was hoped that this method would

¹Doctoral thesis number 1900, submitted Marcy 22, 1957.

Chairman of Committee, J.H. Lilly, Department of Zoology and Entomology.

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provide clues which might help explain the observed effects of different chemical treatments on wireworms.

Seed treatments with aldrin, heptachlor, dieldrin, and endrin failed to show appreciable phytotoxic effects due to these insecticides used at the dosages commonly recommended. All of the lindane seed treatments tested in which the rate of application was one and one-eighth ounce of insecticide per bushel of seed were phytotoxic in laboratory tests. Field conditions tended to reduce the degree of lindane toxicity, although decreases in yields and stands occasionally resulted from as little as one ounce of lindane per bushel of seed. Two ounces of lindane per bushel were quite phytotoxic, and usually resulted in considerable decreases in stands and yields.

Aldrin and heptachlor appeared to be the respective first and second choices among the insecticides investigated, both from the standpoint of potential usefulness in killing wireworms and in protecting treated seeds from attack. Under the conditions of these tests lindane ranked behind heptachlor in killing wireworms, and dieldrin was in fourth place. Endrin showed little toxicity against wireworms in these experiments.

Data are presented to support the hypothesis that all of the insecticides tested repel wireworms to some extent, and that this repellency has the following components: (1) inhibition of the feeding reaction (type one repellency), and (2) orientation of the insects away from the treated seeds (type two repellency). Type two repellency does not preclude the possibility of insect contact with treated seeds, but infers that after a wireworm has reached the vicinity of treated seeds it tends to remain near them for a length of time determined by the degree of type two repellency present.

Aldrin and lindane were the most repellent of the insecticides investigated. The relatively greater repellency of aldrin as compared with heptachlor or dieldrin was attributed primarily to type two repellency. However, the relatively high inherent toxicity of aldrin appears to make it first choice among the insecticides investigated, in spite of its repellency. The relatively greater repellency of lindane, as compared with heptachlor or dieldrin, was attributed to a combination of type one and type two repellency. This repellency causes lindane to rank no higher than third among the insecticides investigated from the standpoint of potential usefulness as a seed treatment for controlling wireworms.

Heptachlor and dieldrin showed less type one repellency than lindane, and less type two repellency than aldrin or lindane. It is suggested that the inherent toxicity of heptachlor may make it a better wireworm killer than dieldrin, and that this toxicity combined with lower degrees of both type one and type two repellency makes it a better wireworm killer than lindane.

Wireworm kills tended to increase as the rate of insecticide application increased from one-half to two ounces per bushel of seed under the conditions of our laboratory experiments.

Thiosolve was too phytotoxic to be of practical value as a water-soluble component of insecticide formulations used for treating seed corn. Also, seeds treated with it at the rate of 10.12 ounces per bushel dried slowly and remained sticky for extended periods of time. Triethanolamine oleate, used in the same way for the same purpose, was somewhat phytotoxic and also resulted in seeds that dried slowly and tended to remain sticky. However, there was an indication that triethanolamine oleate reduced the phytotoxicity of lindane to seed corn.

Carbowax 1500W and Carbowax 6000 were found to be of questionable value as water-soluble insecticide diluents in seed-treating formulations, due to slight phytotoxic effects in laboratory tests. However, these effects usually were not apparent in the field experiments, particularly in the case of Carbowax 6000. In field tests Carbowax 6000 appeared to be quite safe when used to formulate aldrin, dieldrin, endrin, or heptachlor, but not lindane. In fact, lindane phytotoxicity seemed to be increased slightly by both of the Carbowax compounds. Also both Carbowaxes tended to slightly reduce insecticidal action

on wireworms, although this effect was small, particularly in the case of Carbowax 6000.

Seeds treated with insecticide formulations containing vermiculite as the diluent resulted in stands and yields of corn just as good as those obtained from comparable commercial formulations in a field test where soil insects were not a problem. Also, in laboratory tests designed to evaluate the toxicity of seed treatments to wireworms the vermiculite formulations gave results equal to those obtained with the commercial formulations.

AN APPLICATION OF LINEAR PROGRAMMING TO FARM AND HOME PLANNING¹

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The purpose of this study is to determine optimum farm plans for beginning farmers, from foundation situations in the soil locality studied. The optimum plans are determined by application of the linear programming technique.

In this benchmark study, long time price relationships between the various crop and livestock enterprises are adjusted to the current price level which is a basis for computation of input-output data. Three farm situations under average management and five under superior management include many of the management decision problems facing owner-operators in the Southern Pasture Region of Iowa. These situations are studied to determine the optimum plans of operation at different capital levels.

The objective of research is to discover new facts and to develop valid relationships. In this study optimum farm plans are derived to provide a basis for recommending particular forms of farm organization.

The representative farm used for this study is in Adams County where the cropland is largely Sharpsburg and Shelby soil types, with the former representing at least 60 per cent of the cultivated area. Owner operation of a 240 acre farm with 152 cultivated acres, is used for study. Service buildings for the farm include: sufficient storage space for all crops raised on the farm; 895 square feet of floor space for fattening hogs plus sufficient farrowing space in portable farrowing houses; barn space for 20 dairy cows; and poultry housing for 200 hens with brooder space for the necessary baby chicks.

Labor for farming operations in all of the situations, except one situation including pasture renovation, is furnished by the operator and his family. Housewife labor to care for the poultry flock is assumed. Hence, labor to care for poultry is excluded from labor restrictions. In the pasture renovating situation, the alternative of hiring extra labor was included in the farm situation. Another variation of available resources, considered in this study, is increasing the size of the farm to the limits of available labor.

Special attention is given to situations including the Grade B dairy activity under two levels of management. For comparison purposes situations excluding Grade B dairy under average management and excluding both milk cows and Grade B dairy under superior management were studied.

The specific objectives of this study are, given the farm situation, to show profit maximizing farm plans for relevant amounts of capital and other

¹Doctoral thesis number 1864, submitted December 12, 1956. Chairman of Committee, Earl O. Heady, Department of Economics and Sociology.

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resources, making comparisons between plans, and estimating the cost of adopting certain low risk plans. Optimum farm plans and the resulting profits are obtained by the linear programming technique.

In all plans shown, the Shelby cropland use is determined by the livestock enterprises. The Sharpsburg soils use the CCOM rotation throughout but the rate of fertilizer changes with capital levels and moves to the highest rates only when capital is nonlimiting and dairy cows are not in the plan. For the average manager operating without a Grade B dairy enterprise, 11 milk cows are in the optimum plan at both the \$5,000 and \$10,000 capital levels. Hogs represent the next most profitable investment at low capital levels; hogs fully utilize all hog building space in the plans using high levels of capital. As capital increases above \$10,000, commercial heifers and deferred steers replace the milk cows. When Grade B dairy cows enter the plan, no other livestock can compete for resource use at the lowest capital level. At the \$10,000 capital level the dairy herd size increases and hogs enter the plan. At the nonlimiting capital level hog numbers increase and commercial heifers are included. The laying flock is included in all plans with capital nonlimiting. Plant including the Grade B dairy enterprise have higher returns than those excluding this enterprise at all capital levels. Permanent pasture is rented out at the low capital levels.

Under superior management, for both crops and livestock, hogs enter the plans first when milk cows and Grade B dairy cows are excluded. As capital increases the hog enterprise is followed by deferred steers, medium steers, and hens in the order listed. With a 12-cow minimum for Grade B dairy this enterprise enters the optimum plan only at the \$12,146 capital level. At higher or lower capital levels optimum plans include less than 12 Grade B cows under superior management.

In the low risk plans, livestock enterprise combinations of 16 Grade B dairy cows are "forced into" the plan under average management and 12 Grade B dairy cows and 9 beef cows are "forced in" under superior management. Returns are reduced approximately 10 per cent below the competitive plans which exclude all dairy enterprises.

The results of the pasture renovation situation are in agreement with previous research. Pasture renovation enters the optimum plan only at a capital level of \$27,211, after land purchase has been omitted as a possible alternative and after labor restrictions have been relaxed to permit labor hire in the spring and fall. In this extreme situation, pasture renovation enters the plan only at a point where the returns to capital are below six per cent. Alternative investments carrying a greater return are available to most farmers.

When the land buying activity is included as an alternative, pasture renovation is eliminated from the plan and farm size increases from 240 to 483 acres in the plan with nonlimiting capital. Thus, under the assumptions of this study, the family size farm in Adams County could include 483 acres consisting of 306 acres of cropland, 151 acres of permanent pasture, and 26 acres in building site, roads, and waste.

The optimum plan, including land buying gives more than six per cent return to the last increments of capital. At this level of return on capital, the increase of farm size from 240 to 480 acres provides a favorable alternative for owner operators if they have obtained a 50 to 75 per cent equity in their current investment. When equities are below the 50 per cent level, risk aversion and uncertainty factors hinder the growth of farm size. A comparison of 1954 census with 1949 for Adams County shows a 17.6 per cent increase of farm numbers in the 260 to 499 acre size group. Significantly, during this same period farm numbers decreased in every size group below 260 to 499 acres, in Adams County. This study indicates that the number of farms in the 240 to 483 acre range will continue to increase rapidly.

FINANCIAL ORGANIZATION IN FARMER COOPERATIVES¹Wilbur Richard Maki²

Department of Economics and Sociology

Financial organization in farmer cooperatives comprises the financial structure and the processes of management and planning. It was the purpose of this study, therefore, to analyze and to compare historical and optimum financial organizations in specified financing situations and to evaluate the application of an integrated approach, i.e., activity analysis of linear programming, to financial management and planning in farmer cooperatives.

It was postulated in the study that members patronize their cooperative to increase their individual farm profits. Cash payments on deferred patronage refunds and other economic benefits of membership serve as inducements to participation and are maximized over the anticipated period of membership in each individual case.

The maximization of the net benefits of membership over time was accomplished within a specified structure of (1) available technology and (2) resource, market, and financing limitations using the linear programming approach. Four unique financing situations were used to specify the input-output relationships, which were affected by (1) the competitive market position of the cooperative, and (2) the nature of its management. Lack of quantitative information on these factors required the use of the four generalized financing situations as a first approximation to the actual economic conditions in a specific case.

Basic data to test the analytical models were obtained from two main sources: (1) financial and operating statements of a sample of cooperative elevator associations audited by the Farmers Grain Dealers Association of Des Moines, Iowa, over a period of four to ten years, including fiscal years ending during the 1953-54 marketing season, and (2) field survey of 160 members in eight cooperative elevator associations. A population of 172 cooperative elevator associations was stratified into two levels of average net savings over a four-year period and two levels of change in total assets over the same period, i.e., fiscal years ending October 1, 1950 to September 30, 1953. Samples of 86, 32, and 8 associations were obtained for historical and cross-sectional analyses. In addition, supplementary financing data were obtained by mail questionnaires from selected elevators in the sample of 86 associations.

Multiple regression equations were derived, using the least squares method, which provided the merchandising coefficients to describe the input-output relationships for each financing situation. Unit values, or prices were also estimated for each financing and merchandising group, using the same methodological procedure. Finally, quantitative measures of requirements and limiting factors were obtained from the membership survey and the financial and operating statements of elevator associations in the sample.

Limitations to the growth and expansion of farmer elevator associations were examined. Market, resource, and financing limitations were evaluated in terms of their historical origins, measurement, and impact upon the size and nature of the cooperative association. The limitations were identified with policy considerations in the cooperative association, but the level of management was a critical variable in the structure of limitational factors.

Specific financing limitations included (1) the structure of member preferences, (2) collateral and other financing requirements of lending institutions,

¹Doctoral thesis number 1842, submitted August 17, 1956. Chairman of Committee, Richard Phillips, Department of Economics and Sociology.

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(3) the state laws pertaining to farmer cooperatives, and (4) the productivity of capital on member farms. The preliminary applications show the importance of the first of these limitations, i.e., the structure of member preferences. Member preferences, particularly the financing preferences between equity financing and indebtedness, were as restrictive as the market limitations in certain cases in establishing the over-all organization of the cooperative.

The linear programming applications were intended to illustrate the methodology and data requirements of the technique. The most useful applications would involve a specific cooperative with a unique set of resources, market potentials, financing restrictions, and technology. Moreover, the linear programming matrix should provide for a capital expenditures program as well as a merchandising program and a financial program. Each of the needed improvements in the application of the technique is feasible, however, within the proposed analytical framework.

The analytical approach, employing the technique of activity analysis of linear programming, has tremendous potential application. Anticipated future improvements in available data and computational facilities and procedures will make possible the application of the approach to financing and other management planning problems of cooperative associations. It is a realistic and practical approach, insofar as it involves, not merely the quantitative measure of the technology employed in a particular elevator, but the restrictions that limit the use of the available technology. It will be possible to show the loss in net membership benefits as a result of the various market, resource, and financing limitations. Avenues for improvement of the economic environment of cooperatives will be suggested by the linear programming results. The management, the directors, and the members of the cooperative association may relate the suggested improvements to their structure of preferences and purposes in membership. The suggested improvements may be discarded, but the decision can be made in light of a host of relevant factors.

Two specific recommendations are made in view of the limitations and possibilities of the proposed analytical technique. (1) Research on the management factor in farmer cooperatives; (2) research on factors affecting the competitive position of farmer cooperatives. The research findings in the areas of management and industry structure would make possible the application of a general programming approach to specific financing and other organizational problems of farmer cooperatives.

Finally, the place of membership education in the purposes, business operations, and economic possibilities of farmer cooperatives cannot be over-emphasized. The survey data cited in the first part of this study emphasized the wide gap between present membership participation and the level of participation assumed in the analytical model.

COST CONTROL OF SAMPLE SURVEYS BY TWO-STEP DESIGNS¹Carl Ernest Marshall²

Department of Statistics

The design of a sample survey is frequently guided by the well-known principle of obtaining maximum precision of estimates at a given cost. The formulas for "optimum design" resulting from this principle usually involve the parameters of cost functions which are assumed to be known from "past experience". Such assumptions may, of course, be unwarranted, particularly if the survey involves operations of an untried nature.

An attempt is here made to deal with this difficulty by what are called "two-step sampling schemes". With these designs a survey proceeds in two steps:

(1) A first step survey involving a fixed sample size, n_1 , is carried out and in this process data on the cost of the operations are collected.

(2) Based on the cost information under (1), the size, n_2 , of a second step sample is determined by a formula, a " n_2 -rule" designed to control the expected cost of the total survey.

The problems associated with two-step sampling are here treated only for the simplest designs and the most elementary cost functions. They may be classified into two general areas: (a) construction of estimators which combine the results of the two samples, (b) formulation of rules for determining n_2 , the size of the second step sample. Certain of these problems have been investigated in connection with three types of designs, (i) simple random, (ii) stratified random, and (iii) two special cases of two-stage. In each of these designs, discussion is limited to equal probability sampling systems and to simple expansion estimators.

To estimate the population mean two estimators were investigated:

$$\bar{y}_a = a_1 \bar{y}_1 + a_2 \bar{y}_2 \text{ and } \bar{y}_p = p \bar{y}_1 + (1-p) \bar{y}_2. \quad a_1 \text{ and } a_2 \text{ are constants while } p = \frac{n_1}{n_1 + n_2}$$

is a variable depending on n_2 and hence on the results in the first step sample. \bar{y}_1 and \bar{y}_2 are estimates of the population mean approximately obtained from the first and second step samples, respectively. The estimator \bar{y}_a is an unbiased minimum variance estimator providing $a_1 + a_2 = 1$ and a_1/a_2 satisfies a specific condition depending on the type of design being used. The estimator, \bar{y}_p , is a biased estimator--the bias resulting from the covariance between p and \bar{y}_1 . However, if the variable being used in the n_2 -rule is independent of the character being estimated, the estimator is unbiased. The optimum properties of \bar{y}_p were not investigated; however, it does have two very desirable properties: (1) the sample means are weighted proportionally to the size of the samples, and (2) when p and \bar{y}_1 are independent, $\text{Var } \bar{y}_p = \frac{S^2 \bar{P}}{n_1} = S^2 E \frac{1}{n_1 + n_2}$

has a precision like that of a mean based on an "expected sample size of $n_1 + n_2$ ". The variance of each of the estimators was derived. The above results are independent of the specific n_2 -rule, providing, of course, that the rule is determined from information in the first sample.

Although a fairly general class of cost functions is considered, most of the specific results obtained are based on the following assumptions: (1) to each sampling unit there is associated a cost value, and (2) the expected total cost is a linear function of the sample size. In addition to these, occasional simplifying assumptions as well as certain approximation procedures were introduced and tested on the cost records of two surveys--one urban, one rural.

¹Doctoral thesis number 1846, submitted October 4, 1956.

Chairman of Committee, H. O. Hartley, Department of Statistics.

²B.S., Oklahoma Agricultural and Mechanical College, Stillwater. M.S., *ibid.*

The n_2 -rule used was as follows:

$$n_2 = \frac{C_p}{\bar{c}_1} - n_1 \quad \text{if } \bar{c}_1 < c_0 \text{ and } n_2 = n_0 \text{ otherwise,}$$

where $(n_1 + n_0)c_0 = C_p$. When c_0 is so chosen that $p_2 = \Pr(\bar{c}_1 > c_0)$ is relatively small, then this rule has the effect of causing the expected total cost to be approximately equal to the target budget, C_p . If advance estimates on costs are not too unreliable, then the values in the critical equation, $C_p = (n_1 + n_2)c_0$ may be jointly determined so that P_2 is small. The variation in total cost has two sources: (1) the usual sampling variation due to the random selection of sampling units, and (2) the variation in n_2 , the second step sample. If the coefficient of variation of unit cost is small then the variation in n_2 will be small and the contribution to the variance from the second source may be negligible.

In addition to a rule for determining n_2 some suggestions for appropriate choices of the other design parameters n_1 , n_0 , and c_0 are given. An alternative n_2 -rule based on a nonlinear cost function was examined briefly.

Results of simple random sampling was extended to stratified sampling and to two-stage sampling under the limitation of proportional allocation of secondaries and using the customary cost function whose expected value was a linear function of the sample size.

SOIL CLASSIFICATION IN POLK COUNTY, IOWA¹

Ralph Joseph McCracken²

Department of Agronomy

A study and appraisal of soil classification was made which was delimited to Polk County, Iowa. The present widely used approach to soil classification, the multicategorical taxonomic scheme, was used as a basis for this study. Evolution and development of this approach to soil classification since its inception by Russian soil scientists in the late nineteenth century is traced.

Greatly increased numbers of soil series and mapunits in the past 50 years of soil classification and mapping in the Polk County area with attendant shifts in concept and nomenclature are shown. Lack of any appreciable discussion of the rationale and underlying logic for these changes is indicated as one of a number of reasons for undertaking the present study. Other factors involved in undertaking this study were the inherent defects and indicated need for revision of the multicategorical taxonomic approach and the need for evaluation of alternative or complementary approaches to soil classification.

It is concluded from this study that the multicategorical approach is acceptable, but that there is need for revision of criteria for classes at many of the categorical levels. The concept of soil modality as a specific test for placement of soils in classes is rejected, though this concept seems useful as a mental tool or model. An alternative conceptual or type-group approach is suggested whereby classes are defined in terms of common characteristics.

A functional, factorial approach to soil taxonomy and genesis studies was

¹Doctoral thesis number 1850, submitted November 12, 1956.

Chairman of Committee, F.F. Riecken, Department of Agronomy.

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evaluated. It is concluded that this approach contains such a large number of mechanical difficulties in its application that it cannot be considered an alternative to the multicategorical approach. However, it seems extremely useful as a complementary subsidiary approach when employed in qualitative fashion in soil studies.

It is concluded that in the present imperfect state of knowledge about soils and significance of their properties that soil classification cannot at present be a truly natural taxonomic system but must be diagnostic in nature, particularly at lower levels of generalization such as the soil series category. It is suggested that agricultural relevance serve as a choice criterion for selection and weighting of differentiating characteristics except where utility of the class for other uses would be decreased.

Physical and chemical data for a number of Polk County soil profiles were obtained and are presented in tabular form. These data and morphological descriptions have been drawn upon for classification studies.

General soil genetic trends in Polk County on the basis of soil profile data obtained in this study and previous studies of Polk County soil profiles (White, 1953; Folks, 1954; Prill, 1955) are summarized.

Soil horizons, or genetic layers, have been quantitatively defined in terms of properties of Polk County soils. Some modifications of current soil horizon nomenclature and designations are proposed.

Specific suggestions for revision of higher categories of the multicategorical soil classification:

1. Abandonment of concept of soil zonality as a criterion for classes at highest level of generalization and substitution of classifications by array (based on "classification by series" as developed by Mill, 1868) according to degree of display of the most important soil properties. This serves to remove the bias of the "normal soil" concept and places classification on basis of fundamental soil properties as reflections of dominant soil-forming processes. It is postulated that most fundamental property is possession or absence of a B horizon. It is therefore proposed that soils be stratified into classes at the highest categorical level according to major kind of B horizon or lack of B. Two such classes occur in Polk County--those soils in which silicate clay accumulation in B is dominant process and those lacking in B horizons.

2. Abandonment of genetic-ecologic basis of definition of classes at second highest level is advocated with replacement by array of soils according to presence or absence of secondary soil horizons, such as Ae and Bg as defined in this study.

3. Essentially no modification of current concepts of great soil groups is suggested except redefinition of Wiesenboden group to indicate presence of gley B as defined in this study.

Principles and criteria for classes at intermediate levels of generalization are presented. Classification of Polk County soil series into great soil subgroups and soil families on basis of these principles and criteria are given.

A number of problems of soil series differentiation in Polk County are discussed and possible solutions suggested.

Reorganization of current soil type and phase concepts is proposed. Those profile or point properties now used as phase criteria are proposed to supplant or to be given equal status with the current criterion of surface soil texture for the soil type category, the lowest level of generalization. Those shape characteristics of soil, or properties associated with the three-dimensional nature of soil, now used as phase criteria are suggested as a basis for subsidiary classification composed of classes called *utiles*, which could be used to subdivide any taxonomic category.

Relationships among great soil groups of Iowa and among Clarion, Nicollet, and Webster soil series are shown by means of three-dimensional plots. Properties are selected for plotting by application of a deductive system.

Problem areas in soil classification requiring such further consideration

and study are:

1. Weighting of criteria for classes at all levels of generalization.
2. The range, concept, and definition of the soil series--the basic mapping and taxonomic unit.
3. Whether soil classification should attempt to approximate natural classification or be a diagnostic (intermediate between natural and artificial or technical) classification.

LOWER OXIDATION IN GALLIUM HALIDES¹

Richard K. McMullan²

Department of Chemistry

The lower oxidation states in anhydrous gallium halides have been characterized by preparative methods and certain physical measurements.

The gallium dihalides (chloride, bromide, and iodide) have been prepared by the reduction of gallium(III) halides with gallium or by the direct union of gallium and the halogens. Gallium(I) tetrachloroaluminate has been prepared by the reduction of gallium(III) chloride with aluminum or by the reduction of gallium(III) chloride with gallium in the presence of aluminum(III) chloride.

The phase diagram for the system gallium-gallium(III) iodide has been constructed. Gallium(III) chloride and gallium(III) bromide have been equilibrated with excess gallium (in the fused state) in order to determine whether gallium(I) chloride or bromide exists in a condensed phase.

X-ray powder diffraction data have been obtained for the following compounds: Gallium dichloride, gallium diiodide, gallium(III) iodide, gallium(I) iodide, and gallium(I) tetrachloroaluminate.

The molecular weight of gallium dichloride has been determined cryoscopically in benzene using a thermistor as a resistance thermometer. Cryoscopic data have also been obtained for gallium(I) tetrachloroaluminate. These measurements reveal that the basic unit of gallium dichloride is Ga_2Cl_4 and further, that both gallium dichloride and gallium(I) tetrachloroaluminate form aggregates in benzene. The cryoscopic data for gallium dichloride have been analyzed in terms of association of Ga_2Cl_4 into $(\text{Ga}_2\text{Cl}_4)_2$ and $(\text{Ga}_2\text{Cl}_4)_3$.

The dielectric behavior of benzene solutions of gallium dichloride has been examined. Solution densities have been determined and the dipole moment of gallium dichloride calculated to be 8.9 Debye units.

The Raman spectra of gallium dichloride and of silver tetrachlorogallate have been obtained in benzene. The results indicate that the tetrachlorogallate anion is common to both solutes.

The following conclusions have been reached as to the nature of the lower oxidation states of gallium in the halide systems.

1. Gallium(I) iodide exists as a stable solid phase but melts with slight disproportionation into gallium diiodide and metal. In the fused state, gallium(I) chloride and gallium(I) bromide exist in equilibrium with gallium and the corresponding gallium dihalide, but only the monobromide is stable in the solid phase.

2. The basic structural unit of the gallium dihalides is $\text{Ga(I)} \text{ Ga(III)X}_4$. The compounds are, therefore, intermediates in the GaX-GaX_3 systems.

¹Doctoral thesis number 1848, submitted November 5, 1956.

Chairman of Committee, J.D. Corbett, Department of Chemistry.

²B.S., Mississippi State College, Starkville.

Research Assistant, Institute for Atomic Research.

3. In benzene, gallium dichloride exists as the highly polar ion-pair $\text{Ga}^+\text{GaCl}_4^-$ as do the species $\text{Ag}^+\text{ClO}_4^-$, $\text{Ga}^+\text{AlCl}_4^-$, and $\text{Ag}^+\text{GaCl}_4^-$. The aggregation observed with $\text{Ga}^+\text{GaCl}_4^-$ and with $\text{Ga}^+\text{AlCl}_4^-$ is due to the association of these dipolar species into multipolar units.

4. The extent of disproportionation of gallium(I) halides into metallic gallium and gallium(I) tetrahalogallates decreases in the order chloride, bromide, iodide because of the decreasing stability of the tetrahalogallate anion. It is possible to stabilize gallium(I) chloride by the presence of the Lewis acid AlCl_3 which complexes the chloride ion causing the disproportionation. The product, $\text{Ga}(\text{AlCl}_4)_2$, is structurally and chemically similar to gallium dichloride, $\text{Ga}(\text{GaCl}_4)_2$.

RELATIVE EFFICIENCIES OF FARM TENURE CLASSES IN RESOURCE USE¹

Walter G. Miller²

Department of Economics and Sociology

The problems delimited for this study involve the effects of farm operators' tenure status on efficient resource allocation. With the use of 1954 data from a stratified-random sample of farms the objectives were these: (1) to further explore single equation models as means for estimating and comparing efficiency in resource use within farms operated under different tenure classifications; and conjointly, (2) to gain further insights into the relationships between the tenure status of farm operators and the use and productivities of resources employed in Iowa and northern Illinois, the area from which data were obtained. The tenure classes considered were owner-operators, part-owners and full tenants as tenure types, and livestock-share and crop-share-cash renters as lease types.

The hypotheses tested were concerned with the relations between the selected tenure classes and (a) gross output-input fractions, (b) patterns of resource marginal returns, and (c) the achievement of optimum resource combinations at given levels of production. The regression models applied for testing the hypotheses were (1) $Y = \mu + \beta X + \epsilon$, where Y refers to gross production in dollars and X refers to gross resource services also in dollars,

and (2) $\log Y = \log \mu + \sum_{i=1}^3 \beta_i \log X_i + \log \epsilon$, where the resource categories (X_{i-s}) were land and capital services in dollars and labor in weeks. As in the first model Y denotes gross production in dollars.

With respect to the first hypothesis, there were no differences in the estimated gross average output-input coefficients for the tenure types. The difference between the two lease types is significant but the relationships appear to be "unstable." Further, livestock-share renters had an output-input coefficient smaller than that of crop-share-cash, but one possible explanation is the larger average scale of operations under livestock-share leasing. Results also show that at two different levels of gross resource inputs, owner-operators (the least efficient) are 91.1 and 91.8 per cent as efficient as full tenants (the most efficient). But again, "indices of comparative efficiency" are not significantly different.

¹Doctoral thesis number 1849, submitted November 10, 1956. Chairman of Committee, John F. Timmons, Department of Economics and Sociology.

²B.S., University of California, Berkeley. M.S., *ibid.*
Associate, Agricultural Experiment Station.

From the analysis of resource marginal returns, findings indicate that in relation to the opportunity costs assumed, the marginal return to labor is low and the marginal return to capital services is high for the owner-operators. Thus, as expected, resource allocation could be improved with the use of more capital services under owner-operatorship. For part-owners, only the marginal return to labor is "low", indicating excess labor as in the case of owner-operators. To absorb the excess labor thereof, the use of either land or capital services (or both) could be extended, with priority given to land.

From the patterns of marginal returns under the two lease types, no evidence is given of resource excesses. All marginal returns here are above the opportunity costs assumed. Therefore the use of all resources may be profitably extended. But only the marginal returns to land (for both lease types) are significantly above the opportunity costs assumed for land. However, marginal returns under crop-share-cash are consistently lower than those under livestock-share leases. It is proposed that the consistent differential stems from one or a combination of (1) inferior management, or (2) differences in product combinations for crop-share-cash renters. The findings also pose another hypothesis; that "imperfections" generated by leasing arrangements are negated, on the average, by the sharing of uncertainties and the joint contribution of landlords and tenants to the total farm assets.

Contrary to expectations, the significant differences between tenure classes in the levels of marginal returns are few: these are in the marginal returns to land and to capital services for owner-operators versus the two lease types. But still, these "differences" may be traced to possible "biases" in the estimating equations used and to the estimated input of land. Furthermore, the analysis seems to be confounded by labor quality as affected by the differences in the age distribution of operators under each tenure and lease type.

According to the analysis on deviations from optimum resource combinations the younger owner-operators are the most efficient--the average deviation from minimum cost being 2.5 per cent. On the other extreme, crop-share-case renters are the least efficient with the deviation of 4.7 per cent. However, it is very doubtful that the differences in deviations--levels of efficiency--are significant. Again the findings cast doubts that the traditional broad classes of tenure, by owner-operatorship and methods of rental payment, are different in terms of achieving agricultural efficiency.

Realizing possible errors and crudities in the specification of the analytical models used, in essence, the evidences from the three hypotheses still suggest that the intra-tenure class variations in resource use are probably greater than the variations between classes. This conclusion is based on the possible heterogeneity of tenure arrangements within each class that affect production decisions in different ways. The relatively small deviations from optimum resource use suggest further, that the inefficiencies present (if any) may have been cancelled by the efficiencies of other individual observations. Thus there is the need for orienting analytical models designed to detect the specific characteristics of tenure within each class that are impediments to production efficiency.

However, it is recognized that both the data and the methods used in this study have weaknesses and could be refined. For example, separate functions for crops and livestock and improved valuation of resource services would probably yield more fruitful results. Also, the resource categories could be expanded since lumping of capital services conceals the way in which more specific capital items are used. Then, too, the data used do not represent a true random sample of farm operators within the selected tenure class. But even with refinements of the data and the methods used in this study, it is still suspected that further analysis of the traditional tenure classes would not show significant differences in resource use.

Evidence points toward the need for removing the effects of factors that are not tenure associated per se. It is presumed that factors such as labor quality, managerial ability, capital position of the firm, and work preferences

affect resource use and productivities and are important to the extent that they are functionally related to the age of farm operators. Although not concrete, the observations suggest that adjustments for "age effects" are necessary. But still, the effects of tenure characteristics that may generate compensating forces to cover up inefficiencies within a tenure-age class remain to be isolated.

ROLLING COEFFICIENT OF FRICTION OF RUBBER TIRES¹

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Department of Theoretical and Applied Mechanics

The development of an equation for the rolling coefficient of friction of rubber tires was approached by considering the energy produced in a tire as it rolls along a runway. It was assumed that the tire was rolling at a constant velocity, that the surface was dry and level, and that the surface on which the tire was rolling was nonyielding.

During the course of this study a correlation of existing tire data and an approximate analytical expression for the vertical deflection of a tire were investigated.

The load-deflection data from existing aircraft rubber tires were correlated by first considering the items that cause or resist tire deflection and then using the tool of dimensional analysis to develop the equation for such correlation. Correlation was achieved by considering the load-deflection curves for a tire with no internal inflation. A tire stiffness factor was included to account for ply rating of the tire selected. The correlation was achieved when a curve of the ratio of vertical deflection to tire diameter (δ/D) was plotted versus a parameter that included vertical load, tire deflection, and tire stiffness factor (WD/v). A single line resulted based on an 18 ply-rating United States Rubber Company tire and a 22-ply rating Goodyear Rubber Company tire.

A torus-shaped figure with constant cross-section was used to replace the actual tire cross-section in developing the equations for vertical tire deflection. A unit-width cross-section cut was taken through this figure and the internal energy resulting from loading the tire was determined. The rim was replaced by a horizontal force and a moment and the inflation pressure was also considered. The deflection of the tire was determined by application of the Castigliano theorem. The tire stiffness factors were determined for the Goodyear 17.00-20, 22-ply rating tire experimental data and the analytical deflection equation, and plotted versus tire inflation pressure. The values of the stiffness factor were corrected for ply rating when applied to other tires. The vertical tire deflection of a tire based on the data from the Goodyear tire can be estimated within 10 per cent of the experimentally measured values.

The equation for the rolling coefficient of friction was developed by considering the energy required to deflect a tire section as it comes into contact with the runway. Part of this energy is lost in the form of heat and this energy constitutes the resistance to rolling. Thus the rolling coefficient of friction can be evaluated from the load-deflection characteristics of the tire. The rolling coefficient of friction can be predicted within 3 per cent of the measured value by the use of this equation.

¹Doctoral thesis number 1915, submitted May 29, 1957.

Chairman of Committee, Glenn Murphy, Department of Theoretical and Applied Mechanics.

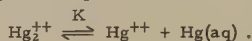
²B.S., Iowa State College, Ames. M.S., *ibid*.

RADIOCHEMICAL STUDIES OF MERCURY
 AND ITS IONS IN DILUTE SOLUTIONS¹
Herbert Charles Moser²

Department of Chemistry

Equilibrium studies have been performed with the objective of elucidating some of the chemical characteristics of mercury and its ions in dilute solutions. Experiments utilizing radioactive mercury tracer to determine low concentrations have been carried out in a threefold area of investigation.

The behavior of mercurous ions in dilute aqueous solutions has been studied. The principal aim of this endeavor was that of resolving between two alternate mechanisms describing the instability of mercurous ions in dilute solutions: dissociation of the dimers into monomeric mercurous ions and dismutation according to the equation:



The ions were found to be unstable toward dismutation, and values of 5.3×10^{-9} and 5.6×10^{-9} were calculated for the dismutation constant K at 25°C. Measurements of the distribution of dissolved free mercury between n-hexane, cyclohexane and dilute aqueous solutions of mercurous nitrate were used to obtain these estimates for K .

The above values for the dismutation constant are in fair agreement with values of 1.8×10^{-9} to 3.6×10^{-9} which were calculated using a different approach. The latter figures were obtained as products of the measurements of the concentration ratio $(\text{Hg}^{++})/(\text{Hg}_2^{++})$ and the solubility of mercury metal. Values of 0.0060 to 0.0120 were found in the literature for $(\text{Hg}^{++})/(\text{Hg}_2^{++})$ for systems containing mercurous and mercuric ions and liquid mercury metal. The solubility of mercury in aqueous solutions was determined in this study to be 3.0×10^{-7} g-atoms per liter at 25°C.

Although the possibility of dissociation of the mercurous dimers into monomeric mercurous ions cannot be completely excluded, the results of this study can be satisfactorily interpreted without considering this effect. The results indicate that a dissociation constant as large as 1×10^{-7} is highly unlikely.

In addition to the determination of the solubility of mercury in aqueous solutions, the solubility of the metal in several organic solvents was measured.

Solubility of Mercury in Organic Solvents at 25°C

Solvent	Conc. Hg $\times 10^6$ observed g atoms/liter	Conc. Hg $\times 10^6$ calculated g atoms/liter
<u>n</u> -hexane	6.1 \pm 6.7	6.2
Cyclohexane	11.0 \pm 0.2	21
Carbon tetrachloride	7.5 \pm 0.3	37
Toluene	12.5 \pm 0.5	48
Benzene	12.0 \pm 0.6	72
Nitrobenzene	9.3 \pm 0.7	157

¹ Doctoral thesis number 1881, submitted January 11, 1957.

Chairman of Committee, A. F. Voigt, Department of Chemistry.

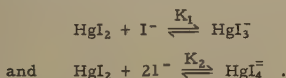
² B.A., San Jose State College, San Jose, California.

Research Assistant, Institute for Atomic Research.

The solubilities which would be expected on the basis of current theory were calculated with Hildebrand's "solubility parameter" equation and are included in the table for comparison with the experimental values.

Distribution constants defined as the concentration of free mercury in the aqueous phase divided by the concentration of the metal in the organic phase were found to be 0.048 for n-hexane and 0.031 for cyclohexane. These compare favorably with the ratios of the solubilities of the metal in water to that in each solvent which are 0.047 for water-n-hexane and 0.028 for water-cyclohexane.

In another area of study, equilibria between mercuric iodide and iodide ions have been investigated. Use was made of the extraction of mercuric iodide into benzene from dilute aqueous solutions of mercuric nitrate containing excess potassium iodide. The results were found to be consistent with the occurrence of the following equilibria:



Values for the equilibrium constants K_1 and K_2 were determined to be $(5.0 \pm 0.1)10^3$ and $(5.1 \pm 0.1)10^5$, respectively.

DISTRIBUTION AND MOVEMENTS OF CHANNEL AND FLATHEAD CATFISH IN DES MOINES RIVER, BOONE COUNTY, IOWA¹

Robert Jess Muncy²

Department of Zoology and Entomology

Recognition of the degree of instability of fish populations is important in most phases of fishery research and management on streams. Past research has obtained various and sometimes conflicting results on movements of channel catfish, Ictalurus punctatus (Rafinesque), and flathead catfish, Pylodictis olivaris (Rafinesque). During a 2-year population study on a 7-mile portion of the Des Moines River, 3,077 channel and 168 flathead catfish were tagged and released from a total of 7,447 channel and 239 flathead catfish.

Size ranges and percentage of recaptures of channel catfish in hoop net and wire trap catches were noticeably greater for period I (April to July 7) than for period II (July 8 to November). These differences in catch could be caused by changes in effectiveness of gear, habits of the fish or migration from the area. Similarly, larger catches and recaptures of adult flathead catfish occurred during June and July.

Hoop net catches of channel catfish were noticeably increased by the presence of ripe female channel catfish. Wide variations in net catches under similar environmental factors prevented the determination of the simple effects of such factors in catch. Comparison of catch per effort with water level fluctuation failed to reveal any relationship. Increased catches in fall were shown by length-frequency to be partially the result of recruitment of age groups 0 and 1.

Reduction in net recaptures during period II, even with cumulative numbers

¹Doctoral thesis number 1883, submitted February 27, 1957. Chairman of Committee, Kenneth D. Carlander, Department of Zoology and Entomology.

²B.S., Virginia Polytechnic Institute, Blacksburg. M.S., ibid. Graduate Assistant, Industrial Science Research Institute.

of tagged fish, indicated dispersal of fish following spawning as well as decreased effectiveness of hoop nets. Anglers' reports indicate that tagged channel catfish traveled as far as 26 miles from tagging locations. Of 92 tagged fish caught by anglers, 63 had moved one-half mile or more from tagging location and 7 of the 63 were taken outside the 7-mile study area, having gone over low-head dams at either end of the area. Only one tag from flathead catfish, which was recaptured at original tagging location, was reported by anglers.

Anglers caught 4 per cent of the channel catfish tagged in first period both in 1955 and 1956, as compared to 1 per cent of those tagged from net catches in the second period. Percentage return from anglers was 1.4 per cent for channel catfish tagged from electric shocker catches. Most of the shocked fish were tagged during the second period. A minimum harvest estimate of 3 per cent was obtained from anglers' tag returns for all fish tagged and a return of 4.5 per cent for tagged fish over 9 inches total length. It would seem that late spring and early summer catches in hoop nets are the channel catfish which contribute most toward the angler's creel.

Examination of hoop net, electric shocking, and angler recapture data revealed no definite migration for channel or flathead catfish, but indicated that foraging may cover considerable distance. Increased activity during the spring and early summer is probably associated with spawning. Tendency of fish to avoid or repeatedly re-enter nets was not detected; instead, recaptures occurred over extended periods of time and seemed only to indicate presence of fish in trapping area. The greatest number of angler returns (14) from a pool at base of a low-head dam suggested that this obstruction was concentrating catfish moving upstream. Anglers' tag returns from deep pools indicate that the catfish population of these pools was not stable but was changing by movement into and out of the area. Data from repeated electric shocking in two sections also suggested that the fish did not remain in same locations or pools week after week.

Habitat preference of large flathead catfish, in addition to minimum net catches in late summer, presented sampling difficulties. Results obtained from limited use of electric shocker-trammel net combination revealed higher densities than were thought to be present. During seven trials with this gear combination at large cover areas, 21 flathead catfish ranging from 13.3 inches to 38.9 inches total length were taken in the trammel net. These fish were not stunned and would not have been taken without the aid of the trammel net. Water depth, current, and floating debris limit the usefulness of this combination. This combination would be useful at times in obtaining large catfish from special areas when they are not being taken in other gear.

Data were also collected on the age and growth of channel and flathead catfish. Increments computed from spine cross-sections measurements, length-frequency, and growth of tagged fish indicated that channel catfish grew less in 1955 than in 1956. Growth was not uniform throughout the entire summer of 1955 but was greatest during June and July. Fish tagged after July 1955 had increased little or none if recaptured before June 1956. Below normal water levels and above normal temperatures may have been the cause of this reduced growth.

Variables, such as missing annuli, unequal erosion of spine center, and changes in shape and location of spine cross-sections encountered in determining total length at each annulus from body-spine relationship, indicate that calculated lengths are at best approximations. Length-frequency and growth of tagged fish generally supported the calculated length data for spine cross-sections. Calculated total lengths at first five annuli were 1.8, 4.9, 7.7, 10.1, and 12.3 inches for channel catfish, and 3.0, 6.4, 9.3, 12.1, and 17.3 inches for flathead catfish. Weight increased approximately as the 3.13 power of the total length for channel and flathead catfish. Annual growth in length decreased with number of annuli but the annual growth increment in weight increased.

Comparison of average ponderal indexes of tagged and untagged catfish

failed to reveal any consistent differences. Tagging may, however, have resulted in slow growth of some individuals. Numbered monel metal strap tags were attached to the opercle. Examination of all fish captured revealed only ten channel catfish with marks on the opercle indicating loss of tags.

The number of eggs ranged from 2682 for an 11.8 inch female channel catfish to 9721 for a 20.2 inch individual.

The many factors found to affect catches of catfish in stationary gear, such as traps and nets, suggest that caution must be used in determining population abundance or trends from catch data. Changes in catfish habits following the spawning season caused noticeable differences in observed catch without any appreciable changes in population abundance.

BOND BETWEEN PORTLAND CEMENT PASTE AND AGGREGATE¹

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The bond between Portland cement paste and aggregate has been investigated with primary attention to the effect of the type of bonding action present in the mineral aggregate. It is postulated that there exists a relationship between the number of ionically bound oxygen atoms present in the mineral surface and the strength of the paste-aggregate bond. Significant correlations have been found between the number of such oxygen atoms and the strength of bond.

The principal test data consist of the results of 7-day and 28-day tensile tests conducted on briquets containing transverse aggregate wafers at varying orientations with respect to the applied force. Aggregate wafers were of sepiolite, neat cement mortar, glass, calcite, chert, orthoclase feldspar, quartz, beryl, and spodumene. Subordinate test data include results of tensile tests on briquets containing polished feldspar wafers and spherical glass inclusions. The properties determined for each aggregate material were the specific gravity, absorption after 24-hour saturation at 22°C and after 5-hour boiling, and rate of absorption per unit area of plane surface at 22°C.

Additional data reported by Thorvaldson (1955-56, Proc. Amer. Concrete Inst. 52:771-80, 1403-13) are included in the study. These data consist of breaking strengths of mortar briquets using 17 pure minerals as aggregates. Strengths are reported for 52-hour moist curing (control), 52-hour curing including autoclave, and 52-hour moist curing (followed by 14-hour water curing).

Evaluation of tensile and shearing stress components on the aggregate surface at varying angles indicates that the breaking strength of the surface between the Portland cement paste and the aggregate is in accordance with the Rankine or maximum normal stress theory, failure occurring for each aggregate at a limiting value of the tensile stress component.

A number designated as effective oxygen ions per square micron is computed for each aggregate on the basis of composition, specific gravity, Avogadro's number, ionic diameter, and percentage of ionic character bonding. It is assumed that remaining oxygen atoms are bound by covalent forces, which yields a number designated as effective valence oxygen atoms per square micron. The significance of the total number of oxygen atoms is also investigated. Equivalent oxygen numbers are computed for the minerals of Thorvaldson's data.

Multiple-product moment correlations and *t* values are computed for each of the oxygen numbers and the rate of absorption against the 7-day and 28-day

¹Doctoral thesis number 1928, submitted June 6, 1957. Chairman of Committee, Glenn Murphy, Department of Theoretical and Applied Mechanics.

²B.S., Kansas State College, Manhattan. M.S., ibid.

average tensile strengths, and also against the strength gain from 7 to 28 days, of the principal test data. Product moment correlations are also computed for each of the oxygen numbers against the three strength values, and also against the strength gains from 52-hour control to each of the other values, for Thorvaldson's data.

Significant t values are approached between the number of effective oxygen atoms per square micron and the 28-day average tensile strength of the principal test data. Significant correlations are found between the number of effective oxygen ions per square micron and the breaking strengths after 52-hour cure with autoclave from Thorvaldson's data.

EFFECT OF CORN RESIDUE ON NITROGEN AVAILABILITY IN SOILS¹

Robert Dean Munson²

Department of Agronomy

This investigation has been conducted to study the effects of corn residue upon the availability of soil and fertilizer nitrogen, to determine the effects of corn residue and fertilizer nitrogen upon the rate of immobilization and mineralization of nitrogen, and to study the effect of time of residue application upon nitrogen availability. Utilizing both field and greenhouse experiments, the objective has been to provide the soil scientist with added knowledge pertaining to crop-nitrogen-residue relationships to aid in decision making and to suggest, where possible, new avenues for research.

In the field investigations, which involved three nitrogen-corn residue experiments conducted during two years on three different soil types, replicated split-split plot experiments were employed, using oats as the test crop. Both nitrogen and chopped corn residue were applied in the fall and spring. Four levels of nitrogen and two levels of residue were used. The oat plots were sampled during the season and at maturity, and total dry matter and nitrogen yields were determined for each sampling. Oat grain yields were also determined at maturity.

Three nitrogen-corn residue greenhouse experiments were conducted, using varying rates of nitrogen and corn residue with and without previous periods of incubation before planting the test crops. In one experiment the pots were treated as mentioned above, but half of the cultures were leached with distilled water in order to determine the effect of residue and added nitrogen upon nitrogen transformations in the soils. Both the leached and unleached pots were then cropped with oats. The greenhouse measurements included dry matter yields and nitrogen yields, and inorganic nitrogen determined on the leachate.

In the field in 1953, 3 tons of chopped corn residue had little negative effect on nitrogen availability as indicated by nitrogen yields. At maturity, the nitrogen yields of the residue and nonresidue plots were essentially equal. The residue, in some cases, decreased the availability of fertilizer nitrogen more than that of the soil nitrogen. In the 1956 experiment, 4 tons of chopped corn residue actually increased both the nitrogen and oat grain yields. This is believed to have been due to the moisture conserving effects of the residue.

In the greenhouse experiments, corn residue markedly reduced nitrogen availability as indicated by dry matter and nitrogen yield of oats. Added nitro-

¹Doctoral thesis number 1917, submitted May 29, 1957.

Chairman of Committee, John Pesek, Department of Agronomy.

²B.S., University of Minnesota, Minneapolis. M.S., Iowa State College, Ames. Graduate Assistant, Agricultural Experiment Station.

gen tended to nullify the effects of the corn residue. Increasing quantities of nitrogen were immobilized in the presence of a given quantity of residue with increasing levels of nitrogen, and the rates of immobilization or mineralization at a given point in time in the presence of residue were increased considerably with increasing levels of nitrogen. Initially immobilized nitrogen, however, was released later during a period of incubation.

It is concluded that in the field, under the experimental conditions that existed, corn residue had little effect in reducing nitrogen availability to the oat crop. In some cases, residues may actually increase the availability of nitrogen, due to their moisture-conserving effects. If soil is deficient in nitrogen, it is necessary to apply nitrogen for the crop's benefit, but not for the decomposition of the residue. Furthermore, it is concluded that in the greenhouse experiments in the presence of residue, large quantities of nitrogen are immobilized and that the quantity of nitrogen immobilized by a given amount of residue increases as the level of nitrogen applications increases. The rate of nitrogen immobilization and mineralization in the presence of a given application of residue is increased with increasing rates of nitrogen, depending upon the point in time considered. Furthermore, nitrogen that is immobilized is again released for crop utilization. The leaching technique used in this investigation provides an excellent method for studying nitrogen transformations in the soil.

VIRAL SYNTHESIS IN *ESCHERICHIA COLI* B INFECTED WITH ULTRAVIOLET IRRADIATED AND UNIRRADIATED BACTERIOPHAGE¹

Robert Leland Nutter²

Department of Physics

A series of experiments on the multiple infection of the bacteria *Escherichia coli* B by ultraviolet (UV) irradiated T₂r+ or T₄r+ bacteriophage was performed, with simultaneous experiments employing multiple infection on identical bacteria by unirradiated phage as controls.

Multiplicity reactivation is the name given to the phenomenon in which the effective survival of ultraviolet irradiated bacteriophage is greatly increased by the simultaneous infection of a bacterium by more than one irradiated bacteriophage particle. Multiplicity reactivation, which ordinarily takes place with the T even phages, did not take place with either T₂r+ or T₄r+ when multiple infection of bacterial cells, which were grown to a limited concentration in a synthetic glucose-salts medium with limiting glucose, was allowed to take place with phage irradiated with ultraviolet light, of largely 2537Å wave length, to a survival of 0.03 to 0.003. These cells did yield new phage upon multiple infection with unirradiated phage.

Multiplicity reactivation was found to take place in cells grown in a regular glucose-salts medium, containing more than a limiting amount of glucose, if leakage and "lysis-from-without" were prevented by infecting the cells in the medium itself and not in buffer, and in cells grown in a glucose-salts medium supplemented with amino acids, vitamins, and minerals, in which case the cells could be centrifuged out and resuspended in buffer for infection without danger of leakage or "lysis-from-without."

Using one of the systems in which multiplicity reactivation does take place,

¹Doctoral thesis number 1903, submitted April 15, 1957.

Chairman of Committee, Robert L. Sinshcimer, Department of Physics.

²B.A., Emmanuel Missionary College, Berrien Springs, Michigan.

M.S., University of Colorado, Boulder.

multiple infection experiments were carried out with UV irradiated and un-irradiated T_2r+ . The total desocytiribonucleic acid (DNA), as measured by the Dische diphenylamine test on 0.3M trichloroacetic acid precipitates of cultures drawn at various times after infection, increased after a 3- to 5-minute lag period in the case of infection with unirradiated phage. The total DNA curve, after infection with UV irradiated T_2r+ , was similar in shape but lagged behind the former DNA curve by 8 to 10 minutes in each case when the experiments were run simultaneously on separate fraction of the same bacterial culture. The UV absorbing acid soluble components from these same samples were found to increase, in general, with time after infection, and the values for infection with UV irradiated phage were the same as for infection with unirradiated phage for the first 60 minutes, after infection, after which the amount of UV absorbing acid soluble materials in the case of the irradiated phage was greater. The UV absorption spectra of the acid soluble fractions revealed peaks at 260 m μ indicative of nucleic acid breakdown products. The differences between spectra of different samples indicated the presence of protein derivatives also.

Duplicate one-step growth experiments for multiple infection with UV irradiated and unirradiated T_2r+ gave latent periods within one or two minutes of each other and burst sizes of approximately 50 and 100 T_2r+ per bacterial cell respectively.

Premature lysis of the bacterial cells in a chloroform-cyanide mixture indicated a lag period of 8 to 10 minutes in the appearance of active intracellular phage in the case of multiple infection with UV irradiated T_2r+ as compared to their appearance in the case of multiple infection with unirradiated T_2r+ .

A method was developed employing paper electrophoresis for the separation of the free bases cytosine, hydroxymethyl cytosine, thymine, adenine, and guanine in an electric field at a pH of 3.4. The bases were eluted from the papers with 85 to 95 per cent recovery. Since the DNA from T even phages contains hydroxymethyl cytosine but no cytosine, while *E. coli* B DNA contains cytosine but no hydroxymethyl cytosine, a quantitative estimation of the amounts of these two bases in a mixture, was used to assay for relative amounts of *E. coli* B DNA and T_2r+ DNA originally present in a mixture of the two after separation of the DNA from other materials and an acid hydrolysis of it to the free bases. This method was employed to estimate amounts of T_2r+ DNA and *E. coli* B DNA present in an infected culture at various times after multiple infection with UV irradiated or unirradiated T_2r+ bacteriophage. This information was graphed. The curves for bacterial DNA versus time indicated decreases with time after infection in each of the two cases. The curves for T_2r+ DNA versus time indicated a period of zero increase followed by a rise to a steady rate of production of DNA. The curve for multiple infection with UV irradiated phage lagged behind that for infection with unirradiated phage by 8 to 10 minutes but had the same shape. In the same experiment, simultaneous determinations of active intracellular phage at various times after infection made possible an estimate of the DNA pool size in terms of phage units of DNA per bacterial cell which amounted to 45 to 50 in both the case of infection with unirradiated phage and in the case of infection with UV irradiated phage.

By using 5-methyl tryptophane as an inhibitor of protein synthesis, and adding it at the time of infection or at a later time in simultaneous cultures of bacteria, one multiply infected with UV irradiated phage and the other with unirradiated phage, and reversing the effect at later times by the addition of tryptophane, it was determined that protein synthesis is necessary soon after infection with UV irradiated as well as with unirradiated T_2r+ in order for bacteriophage production to take place. Protein synthesis is necessary for the initiation of DNA synthesis but not for its continuation. There is evidence that some of the steps in the multiplicity reactivation process, after the initial steps, do not require protein synthesis.

INVERTEBRATE FISH FOOD FROM DREDGED AND
UNDREDGED PORTIONS OF NORTH TWIN LAKE¹John Baxter Owen²

Department of Zoology and Entomology

Several shallow Iowa lakes have been dredged to increase their recreational value. The present study was undertaken to determine some of the biological effects of the hydraulic dredging. Since bottom fauna organisms can be expected to be most affected by the dredging and since the bottom fauna are important fish foods, the study placed the principal emphasis upon a comparison of the bottom fauna of dredged and undredged portions of the lake.

North Twin Lake is a long and narrow lake of about 509 acres in Calhoun County, Iowa. An area of 135 acres in the southern end of the lake was dredged to a depth of from 14 to 18 feet in 1939 and 1940. The north end of the lake is from 4 to 7 feet deep. About 92 per cent of the lake bottom is mud, comprising the quiet-littoral zone; the remainder of the lake bottom is the wave-washed sand of the erosion-littoral zone.

Collections were made in 17 periods during all seasons of the year from July 1951 to August 1954. Bottom samples were taken with a quarter square foot Ekman dredge in the quiet-littoral zone along a number of transects perpendicular to the long axis of the lake, with equal numbers of transects in the dredged and in the undredged areas of the lake.

The predominant bottom organisms of the quiet-littoral zone were the larvae of *Chaoborus punctipennis* (Say) and of various Chironomidae. Oligochaetes occurred in numbers in all areas of the lake but were found not to be fed upon by fish.

It was found that the numbers of *Chaoborus* varied little among locations across the lake at each transect. The principal source of variation was along the long axis of the lake. Hence, increasing the number of transects and decreasing the number of samples on each transect materially increased the efficiency of the sampling design. *Chaoborus* larvae from Ekman dredge bottom samples taken in pairs at one location often showed statistically different mean lengths and abundance. It is known that the smaller larvae are free-swimming near the bottom, while the larger larvae are burrowing in habit during the daylight hours. It was suggested that the taking and washing of the first dredge sample at one location may so disturb the actively swimming smaller larvae that the second sample might take a smaller proportion of the small larvae. *Chaoborus*, then, might be sampled more accurately by taking single samples from a greater number of locations.

Chaoborus were more numerous in the dredged than in the undredged zone. Their numbers and weights decreased in the summer, due to the emergence of adults and perhaps because of an increased rate of predation by fish. This numerical decrease in the dredged area was relatively greater in the shallow than in the deeper portions.

Larvae of Chironomidae were present in substantial numbers in both the dredged and undredged zone during all seasons of the year. Chironomidae were more numerous in the dredged zone at all seasons except during July and August, when a somewhat larger standing crop was found in the undredged zone.

The average annual standing crop of *Chaoborus* and Chironomidae was 33.1

¹Doctoral thesis number 1875, submitted December 14, 1956. Chairman of Committee, Kenneth D. Carlander, Department of Zoology and Entomology.

²B.S., Northeast Missouri State Teachers College, Kirksville.

M.S., University of Kentucky, Lexington.

Graduate Assistant, Industrial Science Research Institute.

pounds (net weight) per acre in the dredged area compared to 16.6 pounds in the undredged. On the basis of pounds of crude protein, the comparable figures were 1.89 pounds for the dredged and 0.70 pounds for the undredged area.

It was estimated that Chaoborus punctipennis and several of the important species of Chironomidae had three generations per year in North Twin Lake in both dredged and undredged portions of North Twin Lake. Therefore annual standing crops are probably proportional to the rate of production in the two areas.

Forage ratios calculated for Chaoborus and Chironomidae indicated that black bullhead in 1953 and 1954 and yellow perch and yellow bass in 1954 fed upon a greater percentage of Chironomidae and a lesser percentage of Chaoborus than the comparable percentage of these organisms in the lake bottom. In 1953 yellow perch fed upon Chironomidae in approximately the same ratio as its occurrence in the bottom fauna and fed upon Chaoborus at a somewhat higher ratio than its relative occurrence in the bottom fauna. Yellow bass in 1953 selected Chironomidae and Chaoborus in proportions approximately equal to their relative abundance.

The relative availability of bottom fauna from the dredged zone is unknown. It has been shown that the standing crop of potential fish food per unit area is greater in the dredged zone than in the undredged zone. Yet if we interpret the low forage ratio of Chaoborus, the typical organism of the dredged zone, as being a measure of the relative unavailability, then the Chironomidae of the dredged zone may be equally unavailable.

Sheet erosion of the watershed of North Twin Lake appears to be affecting the lake adversely by covering the sandy erosion-littoral zone with silt. It is suggested that steps be taken to limit erosion and undue sedimentation affecting North Twin Lake. The sandy erosion-littoral zone in North Twin Lake appears to be wider in proximity to the dredged area. It is suggested that perhaps the sandy littoral zone could be enlarged in lakes that may be dredged in the future by making the dredge cuts through the long axis of the lake, rather than in one end.

EFFECTS OF FLOODS AND DROUGHTS ON FISHES OF A SMALL INTERMITTENT STREAM¹

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Department of Zoology and Entomology

Squaw Creek, located in central Iowa, is an intermittent stream approximately 40 miles long and has a drainage area of 240 square miles. Two years of drought, 1953 and 1955, and one year of floods, 1954, were observed. Fish were collected with minnow seines, wire traps, electric shocker, and rotenone.

The method used to estimate the magnitude of changes in the fish population of the stream consisted of seine hauls covering a stream distance of 20 feet using a 20-foot common sense minnow seine. Factors which might affect the seining method were evaluated. Downstream seine hauls resulted in a higher average catch and in the capture of more species of fish than did upstream seine hauls. The first seine haul made in a section of stream did not appear

¹Doctoral thesis number 1815, submitted June 29, 1956. Chairman of Committee, Kenneth D. Carlander, Department of Zoology and Entomology.

²B.S., Illinois State Normal University, Normal, Illinois. M.S., ibid. Graduate Assistant, Industrial Science Research Institute.

to give larger average catches than did the subsequent seine hauls. At lower water levels the average catch per seine haul was higher due to the concentration of fish in the reduced area. There were greater catches per effort between the hours of 9:00 p.m. and 3:00 p.m. than in the daytime. The number of samples necessary to detect a 10 per cent change in the population was 1,118 samples, a 30 per cent change 124 samples, and a 50 per cent change 45 samples. The seining method appeared to be selective for intermediate sized fish (1.0 to 5.0 inches total length), but an electric shocker indicated that larger fish were rather rare in the creek during the period of study.

The Squaw Creek bed is predominantly shifting sand which results in an unstable and unproductive habitat. During most of the study period, bottom fauna organisms could be found only in a few isolated habitats.

The creek was reduced to a series of isolated pools during the drought periods. In the severe winter of 1955-56, fish, in all except one pool, were killed by drying of the pools, freezing of the pools, or by oxygen depletion. Waste water from the College heating plant permitted the fish to survive in the one pool. Low water levels may also create a barrier to the upstream spawning migration of fish from the Skunk River. Spawning of creek chubs was delayed over a month in 1956 because low water kept them from suitable habitat in Squaw Creek.

The effect of drought conditions are not as drastic in bordering ponds as in the creek. The drought of 1953-54 had little effect on the ponds, but the drought of 1955-56 was considerably more serious. The bottom fauna showed a great increase in numbers and volume per Ekman dredge sample in September, 1955. The increase was partly the result of a normal late summer increase in bottom fauna and probably partly the result of concentration of some of the forms as the area of the pond decreased. Severe winter conditions resulted in the complete freezing of the pool resulting in the destruction of the fish and bottom fauna of the pond.

Flood periods are known to decrease the fish population of streams by stranding fish in isolated pools on normally terrestrial habitats, but only one fish was found in pools left in the flooded areas after the August 1954 flood. Flood periods have a beneficial effect upon the stream fish population by allowing fish from bordering ponds to enter Squaw Creek.

The fish population in Squaw Creek is able to survive drought and flood periods only in certain areas or sanctuaries. Even these sanctuaries may not be safe for the fish. As the habitat decreases, predators take many of the fish, and oxygen depletion may cause extensive mortality. If the water is very low, the pools freeze to the bottom killing bottom fauna and fish. During flood periods the small tributaries serve as important sanctuaries. Young creek chubs, Semotilus a. atromaculatus, were found to be quite abundant in small streams following the June 1954 flood.

The bigmouth shiner, Notropis d. dorsalis, comprised over 80 per cent of the fish population in Squaw Creek during the period of study. Red shiner, Notropis l. lutrensis, while much less abundant numerically, was widely distributed and was taken in almost as many samples as the bigmouth shiner. The red shiner appeared to withstand concentration as the habitat decreased with drought better than most other species. Twenty-seven species of fish were collected from October 1953 to June 1956, but four of these were not considered as normally inhabiting the creek.

Most of the species have been successful in maintaining themselves regardless of the drastic changes which occur in the habitat. The fish population changes seem to be rather small compared to observed habitat changes.

VEGETATIVE VIGOR, SEED SETTING, AND SEED SHATTERING
IN SELECTIONS AND CROSSES OF BIRDSFOOT TREFOIL
(*LOTUS CORNICULATUS* L.)¹

Hugh Anthony Peacock²

Department of Agronomy

Birdsfoot trefoil is becoming an increasingly important forage legume in the areas of adaptation. Limiting factors in its distribution have been lack of seedling vigor, inadequate seed supply, and relatively low forage yields. This study was undertaken to investigate the possibility of increasing vegetative vigor, seed production, and resistance to seed shattering through a recurrent selection breeding program. The study consisted, primarily, of the evaluation of four noninbred clones in each of four groups, and the diallel crosses of the noninbred clones within each group. Vegetative vigor was measured by estimating growth habit, recovery after cutting, and by actual forage yields of open pollination progenies and diallel cross progenies. All parent clones in this study were self-incompatible, but each produced enough viable pollen for normal cross-pollination. All clones were cross-compatible in every combination, but, as indicated by actual seed set, there was considerable variability in cross fertility among the various crosses made.

To measure the actual percentage seed pod shattering, seed pods were exposed to a relative humidity of 35 per cent for 72 hours. The dessication chambers were kept in an unlighted room at room temperature. A 72-hour period at 35 per cent relative humidity was found to be necessary to allow the system to come to equilibrium to effect maximum shattering so that the degree of resistance of seed pods to shattering could be differentiated. A correlation coefficient of 0.992, significant beyond the 1 per cent level, expressed the relationship between shattering percentages of the same clones or strains collected on two dates.

Wide differences in susceptibility to seed pod dehiscence existed among clones. These differences appeared to be due to differences in genotypes of the clones. No differences in forage yield were found between crosses and their reciprocals.

Trefoil clones were evaluated by determining forage yields of their open pollination progenies and diallel cross progenies. The clones considered best in general combining ability were those which produced both open pollination progenies and diallel cross progenies of highest yields. Significant differences in forage yield were evident among open pollination progenies within groups and among diallel cross progenies within groups.

Clones having an upright growth habit produced only upright plants in their open pollination and diallel cross progenies. The clones considered best in seed production were those that produced the highest seed production scores in both their open pollination and diallel cross progenies.

The analysis of the open pollination and diallel cross progenies of the thirteen clones for recovery after cutting indicated that plants of the upright type recovered faster after cutting than those of the semiprostrate or prostrate type. Of the progenies studied, those in group I, European upright type, ranked best in recovery after cutting.

The open pollination progenies of the clones in group III, selected specifically for resistance to seed pod shattering, were the most resistant among the open pollination progeny groups, and were more resistant than Iowa Empire

¹Doctoral thesis number 1854, submitted December 4, 1956. Chairmen of Committee, C.P. Wilsie and I.J. Johnson, Department of Agronomy.

²B.S.A., University of Florida, Gainesville. M.S.A., *ibid*. Associate, Agricultural Experiment Station.

or New York Empire. The diallel cross progenies within group III were more resistant to seed pod shattering than the open pollination progenies within group III, and displayed the most resistance among all comparisons based upon both shattering resistance mean scores and actual shattering resistance tests.

Several synthetic recombinations were evaluated for seed pod shattering resistance. The percentage seed pod dehiscence of the first cycle synthetic of the European type, when compared to the original European, was decreased significantly, as were the shattering percentages of first and second cycle synthetics of the Empire type, when compared to the original Empire. The seed pod shattering of the second cycle synthetic of the Empire type was slightly less than that of the first cycle synthetic.

There was little apparent gain in forage yield or in seed setting from two cycles of recurrent selection. However, in each cycle selection was based on multiple criteria and not only on these specific factors.

One cycle of recurrent selection for resistance to seed pod shattering resulted in a shift in the mean of 17.55 per cent.

In recurrent selection studies on forage yield, seed production and resistance to seed pod shattering, the open pollination progeny performance was similar to the diallel cross progeny performance, and in general, could be used to predict the performance of the diallel crosses.

An attempt was made in this study to partition the observed variance or covariance into the environmental and genetic components. In general, genetic correlations were relatively higher than observed correlations indicating that the environment tended to mask the expression of genetic relationships between open pollination and diallel cross progenies for the various characters. The path coefficients indicated that, in general, genetic effects were more important in both diallel crosses and open pollination progenies than were environmental effects.

A correlation coefficient of -0.8676, significant beyond the 1 per cent level, expressed the relationship between growth habit scores and seed production scores, indicating that plants having a more prostrate growth habit produced more seed than those having an upright growth habit.

The relationship between growth habit scores and recovery scores was expressed by the correlation coefficient, 0.6928, significant beyond the 1 per cent level, indicating that plants having an upright growth habit recovered more rapidly than plants having a more prostrate growth habit.

The correlation coefficient, 0.7233, significant beyond the 1 per cent level, expressed the relationship between actual shattering percentage and the shattering scores of open pollination progenies, and a somewhat lower correlation coefficient, 0.4654, significant beyond the 5 per cent level, was found for the relationship between actual shattering percentage and shattering scores of diallel cross progenies.

PROTEIN REQUIREMENTS OF BABY PIGS¹Ernest Ramy Peo, Jr.²

Department of Animal Husbandry

Growth Studies

Four hundred and eight baby pigs, weaned at an average weight of 6.2 lbs and at an average age of 8.3 days, were used in three continuous growth experiments designed to study the protein needs of baby pigs. In all experiments the gains and feed efficiencies of the baby pigs were used as criteria of response.

In the initial experiment, four levels of protein and four levels of fat were studied in a four by four factorial designed experiment with 272 of the baby pigs to determine the interrelated effects of protein and fat levels on gains and feed efficiencies of baby pigs when fed dry meal-type rations.

Response to protein levels for the first two-week test period showed a significant protein linear regression with maximum gains occurring on 30 per cent protein. For the four-week test period, the observed gains when averaged across all fat levels were maximum on the 20 per cent protein rations. Smoothing these gain responses with a multiple regression equation shifted the apparent (predicted) maximum response to the 25 per cent protein rations.

There were no significant differences in gains attributable to fat levels for either the first two-week or the four-week test periods. However the outward appearance of the pigs and the physical characteristics of the rations were improved when fat was added to the rations. Feed efficiency was significantly improved by increasing protein levels for both the first two-week and the four-week test periods.

A subsequent limited investigation revealed that baby-pig gains on 40 per cent protein were less than those made by pigs on 30 per cent protein. Pigs fed 40 per cent protein and 20 per cent fat required less feed per pound of gain than those fed 30 per cent protein and 10 per cent fat.

When three sources of protein and five levels of each were studied, the results showed that the baby pigs fed dried skimmilk as the source of protein made significantly greater gains than those fed Drackett C-1 Assay protein or 50 per cent solvent soybean oil meal for both the first two-week and the four-week test periods. The gain differences between levels within sources of protein were found to be statistically nonsignificant.

Less feed was required per pound of gain by the pigs fed dried skimmilk as a source of protein than was required by the pigs fed Drackett C-1 Assay protein or 50 per cent solvent soybean oil meal. For both the first two-week and the four-week test periods, the differences between the animal and plant sources of protein were shown to be statistically significant. The pigs fed 50 per cent solvent soybean oil meal showed a statistically significant improvement in feed efficiency over those fed Drackett C-1 Assay protein for the four-week test period. As with gain, the feed efficiency differences between levels, within sources were shown to be statistically nonsignificant.

Depletion-Repletion Studies

Ninety-six baby pigs were used in three experiments designed to evaluate the protein depletion-repletion technique as a method for determining the biological value of protein sources for baby pigs.

Results of the first experiment showed that baby pigs could be successfully

¹Doctoral Thesis number 1816, submitted July 5, 1956.

Chairman of Committee, Damon Catron, Department of Animal Husbandry.

²B.S., Oklahoma Agricultural and Mechanical College, Stillwater.

M.S., ibid. Graduate Assistant, Agricultural Experiment Station.

sustained on a protein-free diet for a period of one week. (A subsequent experiment showed that the baby pig could be successfully sustained on a protein-free diet for a two-week period.) When the pigs were protein repleted for seven days, greater gains and feed efficiencies were made by the pigs repleted with dried skimmilk than were made by those repleted with 50 per cent solvent soybean oil meal with or without 0.1 per cent DL-methionine.

Dried skimmilk was selected as the source of protein for establishing the optimum level of protein for the protein repletion of baby pigs which were previously fed a protein-free diet for one week. Of the levels tested (12 to 22 per cent), maximum repletion gains were made by the pigs fed 22 per cent protein and minimum gains were made by those repleted with 12 per cent protein. Generally, repletion gains increased linearly from 12 to 22 per cent protein (the linear regression component of treatment effects was statistically significant). A similar trend was observed in the feed required per pound of repletion gain. However, maximum feed efficiency was shown by the pigs repleted with 20 per cent protein.

Since repletion gains increased linearly from 12 to 22 per cent protein, these protein levels were expanded over a wider range in order to determine the level of protein at which maximum repletion gains might occur. In addition, the effects of protein depletion and repletion on blood components were also determined. In contrast to the previous results, on an average repletion gains reached a maximum at the 18 per cent level of protein and then decreased on higher levels of protein. When the repletion gain data were analyzed, the quadratic regression component of treatment effects was shown to be statistically significant.

The pigs repleted with 12 per cent protein required 1.72 lbs of feed per lb of repletion gain as compared to 1.33 lbs for the pigs repleted with 18 per cent protein. Pigs repleted with levels of protein higher than 18 per cent required more feed (actually only 0.1 lb) per pound of repletion gain than those repleted with 18 per cent protein. For feed efficiency, both the linear and quadratic regression components of treatment effects were shown to be statistically significant.

In this experiment, the effects of protein depletion and repletion on certain blood components were also studied. However, the results obtained were apparently masked by changes in plasma volume. If plasma volume changes had been determined, then it is possible that the protein source and/or levels might have been shown to have had a significant effect on the blood components studied. Changes in the albumin-globulin ratio appear to be the most promising effect of protein depletion and repletion and warrant further investigation.

CHLORIDE CATALYSIS IN SOME REDUCTIONS BY STANNOUS ION¹Norman Cornelius Peterson²

Department of Chemistry

The object of this investigation was to examine the chloride catalysis of stannous ion reductions of ferricinium ion (biscyclopentadienyl iron (III)) and of the diazo group of methyl orange.

The reduction rates were measured spectrophotometrically at 25°C in perchloric acid-hydrochloric acid solutions of ionic strength 2.0. The methyl orange reduction is first order in methyl orange, first order in stannous ion, first order in hydrogen ion, and third order in chloride ion. The reduction of ferricinium ion by stannous ion is first order in ferricinium ion, first order in stannous ion, and fourth order in chloride ion.

These reactions were interpreted in terms of similar mechanisms. The rate-determining step in the methyl orange reduction was postulated as an electron-transfer between the stannous trichloride complex ion and the protonated azo group of methyl orange. The rate-determining step in the ferricinium ion reduction was postulated as an electron-transfer between the stannous trichloride complex ion and the ferricinium chloride complex ion.

The presence of small equilibrium amounts of the ferricinium chloride complex ion, $\text{Fe}(\text{C}_5\text{H}_5)_2\text{Cl}$, in chloride solutions was established by means of absorption spectrophotometry.

The additional chloride ion in the transition state in the ferricinium ion reduction suggests that the cyclopentadienyl rings are effective in shielding the iron atom from electron-transfer, and that a chloride bridge is a much more efficient electron-transfer path. The ferricinium-stannous reaction and the ferric-stannous reaction have similar rate laws, including the same order in chloride ion which indicates very similar mechanisms for the two reactions.

¹Doctoral thesis number 1831, submitted July 30, 1956.

Chairman of Committee, Frederick R. Duke, Department of Chemistry.

²S.B., Massachusetts Institute of Technology, Cambridge.

Graduate Assistant, Industrial Science Research Institute.

DETERMINATION OF DYNAMIC PROPERTIES OF
MATERIAL BY WAVE PROPAGATION¹Paul Weber Peterson²

Department of Theoretical and Applied Mechanics

The object of the investigation is to develop a method for predicting the dynamic properties of a material using wave propagation techniques. The equation predicting the dynamic properties is developed in terms of stress, rate of strain, strain level, and the velocity of propagation of the leading edge of the strain wave. From this prediction equation, a stress-strain diagram for the desired rate of strain can be developed.

¹Doctoral thesis number 1884, submitted February 28, 1957.

Chairman of Committee, Glenn Murphy, Department of Theoretical and Applied Mechanics.

²B.S., Iowa State College, Ames. M.S., *ibid*.

The analysis is made for a material having nonlinear stress-strain relationships. In the analysis, the strain wave traveling through the material is considered to be a single pulse the leading edge of which is assumed to be linear. The analysis is extended to include a material having linear stress-strain relationships as well as for a strain pulse of any shape.

An experimental technique is developed by which quantities appearing in the proposed prediction equation can be evaluated. The experimental technique is applied to a rubber test specimen, and the pulse mechanism used in the experimental investigation develops a strain pulse which has a linear leading edge. In order that a rubber test specimen might be used in the experimental investigation a flexible strain gage is developed and a method is also developed by which the flexible strain gages can be calibrated.

In the experimental investigation, the observed rates of strain were high (250 per cent per sec) and the observed levels of strain were low (500 micro-in per in). The low levels of strain and the high rates of strain made it difficult to obtain experimental data to confirm the predicted values of stress. A method is proposed by which experimental data can be obtained to check the predicted results.

The stress-strain characteristics evaluated from the developed prediction equation appear to be consistent with the results obtained by other investigators, and the method of approach used to obtain the prediction equation is consistent with known wave propagation fundamentals.

EFFECT OF PARTICLE SHAPE ON FLUIDIZATION AND HINDERED-SETTLING¹

Alden Fredrick Presler²

Department of Chemical Engineering

A modification of the original Ruth theory for fluidization and hindered settling of spheres was derived for treating the relative motion of fluids and expanded aggregates of nonspherical solids. The modified theory retained the original Ruth assumption that the forces resisting the motion of a particle within an aggregate are the Stokes' law force acting on a single particle plus a frictional force analogous to that experienced by a fluid passing through a compacted bed of particles. This expression for the average relative velocity, u' , is

$$u' = \frac{\varphi' (\delta - \rho) g D_s^2}{S^2 \mu K_e (1 + F_{ke}) D_s^2 + 18 \varphi' (1 + F_p) \mu}$$

The $1 + F_p$ term is a correction to the Stokes' law resistance for both turbulence and particle shape effects.

Ruth suggested that the $1 + F_p$ term had the form $(1 + F_s)/\sqrt{\varphi}$, where $1 + F_s$ was a turbulence factor for spheres to correct Stokes' law, and φ was the particle sphericity. Ruth obtained the values of $1 + F_s$ from the data of Pettyjohn and Christiansen.

An alternate expression for the $1 + F_p$ term, in which the turbulence and particle shape effects are separated, was used in this work and it had the

¹ Doctoral thesis number 1873, submitted December 14, 1956.

Chairman of Committee, D.R. Boylan, Department of Chemical Engineering.

² B.S., Iowa State College, Ames. M.S., *ibid*.

Graduate Assistant, Engineering Experiment Station.

form $1 + F_p = (1 + F_p)_s f(\text{Re})$, where $(1 + F_p)_s$ is a shape factor modeled after an ellipsoidal shape factor. Since the correction factor $(1 + F_p)_s$ for ellipsoids can be calculated by means of the Oberbeck integrals, it can also be computed for nonspherical particles by assuming that the particle is triaxial, and similar to an ellipsoid. The $f(\text{Re})$ term was determined empirically from the data of Malaika and Pramanik.

The sphericity of Raschig rings, Berl saddles, and groups of 5 mm and 3 mm spheres arranged into chains and pyramids, was determined experimentally from free fall studies of these particles in two fluids having viscosities of 2 and 2000 poises. The experimental sphericities did not check closely the theoretical sphericity for these particle types and the variation was quite large for a given particle. It was concluded that sphericity is not a good shape factor.

The ellipsoidal shape factor $(1 + F_p)_s$ for galena, magnesite, and mica minerals was computed from the three dimensions of the triaxial particles. The particle dimensions were obtained by direct measurement. It was shown from measurements that the average particle dimension ratios were essentially constant. It was also shown that the ratio of the average intermediate dimension to the average screen opening was essentially constant.

The galena, magnesite, and mica ore were crushed and screened into half-mesh Tyler screen sizes. The screened samples were cleaned of fines and gangue in a water elutriator column.

The experimental apparatus was designed so that both fluidization and permeability tests could be run in sequence on a given sample.

The specific surfaces of the particles were determined from permeability tests. The mica specific surfaces were less accurate than the magnesite or galena because of compaction of the bed during the tests. Permeability data were correlated by the method of Ergun.

Fluidization and hindered settling tests were made on the galena and magnesite in the size ranges greater than 80 mesh. The data were correlated by the modified Ruth equation. From these data the Kozeny number $K_e(1 + F_{ke})$ was determined. A composite plot of the fluidization and hindered settling Kozeny number versus the modified Reynolds' number, $4u\rho/\mu(1 - \epsilon)_s$, showed that the effect of nonspherical particle shape was to make the term $K_e(1 + F_{ke})$ essentially independent of the Reynolds' number for completely fluidized beds. Nonspherical $K_e(1 + F_{ke})$ values were somewhat higher than the value of 2.5 found by Loeffler for spheres in the viscous region.

INFLUENCE OF VARYING PROTEIN AND CALORIC LEVELS UPON THE
STILBESTROL RESPONSES IN FATTENING LAMBS AND CATTLE¹Rodney LeRoy Preston²

Department of Animal Husbandry

In the feeding of cattle and lambs, considerable use is made of roughages in the form of range grass, pasture, silage, and hay. In order to provide a desirable meat product, most of these cattle and lambs are fed for a period of time on rations high in concentrates just prior to slaughter. It has been estimated that approximately 80 per cent of the total cost of feeding cattle and lambs is accounted for by feed costs. Thus, any practice which will help in reducing feed costs will materially increase the over-all profits in cattle and lamb production. It has been previously shown that the administration of diethylstilbestrol (stilbestrol), either orally or by implantation, will greatly enhance the gains and feed efficiency of lambs and cattle during this finishing period. It was the purpose of the work reported in this thesis to study the influence of the ration, that is the caloric and protein level of the ration, upon the stilbestrol responses of lambs and cattle, including gains, feed efficiency, and carcass quality.

A total of 246 individually fed wether lambs and 72 group fed steer calves were included in the studies. The lambs were fed in four separate experiments and the cattle in one experiment. Stilbestrol was orally administered to these animals by incorporation into rations which varied in their caloric and protein levels.

It was found that the feeding of stilbestrol will increase gains of both cattle and lambs on rations which were low, adequate, or high in protein. Gains made by lambs were stimulated to a greater degree by stilbestrol on high energy compared to low energy rations. Feed efficiency was affected in a manner similar to the gains. Dressing per cent and cooler shrink were not consistently affected by stilbestrol. Carcass grades were generally increased by increasing the protein or caloric intake, and only slightly decreased by the feeding of stilbestrol. Carcass fatness, as measured by separable fat and fat analysis of the longissimus dorsi muscle revealed that the effect of stilbestrol upon these measurements was dependent upon the energy-protein ratio of the ration. When this ratio was wide, the feeding of stilbestrol caused an increase in these fat content measurements, whereas, when the ratio was narrow, the leanness of the carcass was increased.

Other data collected in the lamb experiments included the weights of several organs and glands, and the serum concentration of glucose and amino acid nitrogen. It was found that the weight of the anterior pituitary, kidneys, and liver was increased by the feeding of stilbestrol, whereas the weight of the adrenal glands was only slightly increased and the thyroid weight was not affected. Serum amino acid nitrogen values were slightly decreased and the serum glucose values increased by the feeding of stilbestrol. The relationship of these findings to the possible mode-of-action of stilbestrol in ruminant animals is discussed.

¹Doctoral thesis number 1927, submitted June 6, 1957.

Chairmen of Committee, Wise Burrough, Department of Animal Husbandry, and E.A. Hewitt, Department of Veterinary Physiology and Pharmacology.

²B.S., Colorado College of Agriculture and Mechanic Arts, Ft. Collins.

M.S., Iowa State College, Ames. Instructor.

EFFECT OF INCOME, FLUID MILK PRICES, AND RACE
ON CONSUMPTION OF FLUID MILK AND FLUID
MILK SUBSTITUTES IN THE URBAN SOUTH¹

Joseph Carroll Purcell²

Department of Economics and Sociology

The primary objective of this study was to estimate the effect of income, fluid milk prices, and race on the consumption of fluid milk and fluid milk substitutes (canned and dried milk) in the urban Southeast. A supplementary objective was to evaluate the use of cross-sectional data in estimating price elasticities and cross elasticities of demand.

Data pertaining to the consumption of fresh fluid milk, canned and dried milk, income, race, and household size and composition were obtained from 1,365 households located in 12 southeastern cities. Cities were purposely selected in order to obtain a range in fluid milk prices with otherwise comparable cities. Households within cities were randomly selected.

Single-equation models were employed in the analysis. Least-squares multiple regression equations were used in the initial analysis to estimate the effect of income, fluid milk prices, race, and household size and composition on the consumption of both fluid milk and fluid milk substitutes. The data were analyzed for all households combined, and for white and colored households separately. Results of the multiple regression analysis were used to obtain average consumption by cities adjusted for differences in income, race, and household size and composition. Simple regression equations, with data converted to logarithms, were employed in the analysis of data by cities in order to obtain estimates of average price elasticities and cross elasticities. Relationships between income and the consumption of fluid milk and fluid milk substitutes at various levels of income were estimated from the multiple regression equations for all households combined, and for white and colored households separately.

Consumption of both fresh fluid milk and fluid milk substitutes exhibited considerable variability among households. Thus it was possible to explain only a relatively small proportion of this variability by the single equation models employed.

Household consumption of fresh fluid milk increased significantly with increased income, but the effect of income on fluid milk consumption diminished as income increased. The estimated effect of a unit increase in the logarithm of monthly income (in dollars) on fluid milk consumption was an increase of 3.74 quarts per week for all households, 3.95 for white households separately, and 2.98 for colored households separately. However, the estimated income elasticities of demand for fluid milk were slightly larger for the colored households than for the white households. A significant negative relationship was exhibited between household consumption of fluid milk substitutes and income. A separate analysis by races indicated a highly significant negative relationship between income and consumption of fluid milk substitutes for white households, but a nonsignificant relationship for colored households.

A negative relationship was exhibited between prices and consumption of fluid milk. The effect of price on consumption was not significant in multiple regression equations including race as an independent variate. A significant relationship was obtained in a separate analysis for white households, but a nonsignificant relationship was obtained for colored households. Price analysis

¹Doctoral thesis number 1878, submitted December 17, 1956. Chairman of Committee, G. Shepherd, Department of Economics and Sociology.

²B.S., Iowa State College, Ames. M.S., *ibid*.

Graduate Assistant, Agricultural Experiment Station.

by cities indicated the possibility of a more elastic (in the range of -2.0 to -3.0) demand for fluid milk than has generally been concluded from time series and market data studies. The statistical evidence was, however, not conclusive. Analysis of cross-sectional data, with careful selection of the markets, offers considerable potential toward a better understanding of the price elasticity of demand for fluid milk.

A highly significant positive relationship was exhibited between the consumption of fluid milk substitutes and the prevailing prices for fluid milk. Highly significant cross price elasticities of the demand for fluid milk substitutes were obtained with prices of fluid milk as the independent variate. In a separate analysis by races, the relationship between prevailing prices for fluid milk and consumption of fluid milk substitutes was highly significant for white households but nonsignificant for colored households. Analysis of adjusted household consumption of fluid milk substitutes and prices of fluid milk by cities indicated an average cross price elasticity of demand for fluid milk substitutes of 1.46.

White households consumed 3.64 quarts more fresh fluid milk per week than colored households in addition to differences in household income, size, and composition. The effect of race on fluid milk consumption was highly significant. Colored households consumed more fluid milk substitutes than white households but the race effect was not significant.

Three age groups--children under four years of age, children four to 18, and adults--were included in the composition of households. The effect of the number of persons in households on consumption of fluid milk was highly significant for all age groups for all households and for white households. A separate analysis for colored households indicated that children four to 18 did not have a significant effect on household consumption of fluid milk. The effect of two age groups--children under four and four to 18--on household consumption of fluid milk was significantly less for colored households than for white households.

The effect of the number of persons in households on consumption of fluid milk substitutes was highly significant for all age groups for all households and for white households. A separate analysis for colored households indicated that adults did not have a significant effect on household consumption of fluid milk substitutes. Children under four years of age had a significantly greater effect on household consumption of fluid milk substitutes than did either children four to 18 or adults for both white and colored households.

Household consumption of fluid milk was positively associated with consumption of milk away from home by members of the household. The relationship was highly significant. Combined household consumption of bottled skim milk, buttermilk, and chocolate milk was not significantly associated with consumption of fresh whole fluid milk. Consumption of fluid milk away from home was not significantly associated with household consumption of fluid milk substitutes. Combined household consumption of bottled skim milk, buttermilk, and chocolate drink was not significantly associated with household consumption of fluid milk substitutes.

SOME REACTIONS OF PHENOTHIAZINE AND ITS DERIVATIVES¹Ralph Oliver Ranck²

Department of Chemistry

Phenothiazine and many of its derivatives are useful as chemotherapeutic agents and antioxidants while others have shown great potential in these and in other fields. It was the purpose of this study to prepare new derivatives of phenothiazine for evaluation of their biological activity and as possible liquid solution scintillators. Their value as scintillators is part of a general program designed to correlate chemical constitution with scintillation activity as well as to find a good scintillator (1).

Since compounds containing the boron isotope 10 have been found to be of interest in brain tumor therapy with azo boronic acids showing the greatest possibilities (2), both boronic acid and azo boronic acid derivatives of phenothiazine were proposed. Some compounds of these types not containing the phenothiazine nucleus were prepared in order to gain experience in synthesizing and purifying such materials. These were submitted for testing (3).

Because many N-substituted phenothiazine derivatives can be prepared in only low or intermediate yields, some new or improved techniques were investigated in order to overcome this deficiency. This phase of the study was also extended to some of the oxidation reactions.

N-substitution can be accomplished by a number of methods. These include reaction between phenothiazine and an organohalide in a sealed tube; reaction between phenothiazine and an organohalide in the presence of an alkaline condensing agent and copper powder, both with and without a solvent; and reaction between 10-sodiophenothiazine and an alkyl halide in liquid ammonia.

The use of a greater concentration of 10-sodiumphenothiazine in liquid ammonia than has been reported previously (4) was found to be advantageous for the preparation of 10-allyl- (b.p. 165-170°/0.7 mm, 92 per cent), 10-ethyl- (m.p. 102.5-104°, 99 per cent), 10-(n-decyl)- (b.p. 175-180°/0.5 mm, 84 per cent), and 10-(n-octadecyl)phenothiazine (m.p. 52-52.5°, 12.9 per cent). Although this last yield is quite low it is very significant since previous attempts to prepare this material in liquid ammonia failed (5). The alkyl bromide was used in each of these preparations except the first, in which case allyl chloride was utilized.

The preparations of 10-(β -phenylethyl)phenothiazine and 10-(β -phenylpropyl)phenothiazine in liquid ammonia using (2-chloroethyl)benzene and (3-chloropropyl)benzene, respectively, were only partially successful, material which could not be purified being isolated in each case. The attempted preparation of 10-(triphenylmethyl)phenothiazine from triphenylmethyl chloride in liquid ammonia gave an unidentified material while no 10-(2-pyridyl)phenothiazine could be obtained by reacting 2-chloropyridine with 10-sodiophenothiazine in liquid ammonia.

10-(n-Decyl)phenothiazine (b.p. 175-180°/0.5 mm), 10-(n-octadecyl)phenothiazine (m.p. 53-54°) and 10-(o-bromobenzyl)-phenothiazine (m.p. 90-92°) were prepared in yields of 87 per cent, 90 per cent, and 88 per cent (somewhat impure), respectively, by treating 10-sodiophenothiazine with the appropriate bromo compound (chloro in the case of the o-bromobenzyl derivative) in tetrahydrofuran. Attempts to extend this technique to the preparation of other N-substituted phenothiazines using iodobenzene, o-iodonitrobenzene, p-iodonitrobenzene, 2-bromopyridine, 2-chloroquinoline, triphenylmethyl chloride and p-nitrobenzyl bromide were unsuccessful.

¹Doctoral thesis number 1891, submitted March 12, 1957.

Chairman of Committee, Henry Gilman, Department of Chemistry.

²B.S., Bucknell University, Lewisburg, Penna. M.S., Purdue University, Lafayette, Ind. Graduate Assistant, Institute for Atomic Research.

Several N-substituted phenothiazine derivatives were prepared successfully by heating phenothiazine and a halogen compound in the presence of sodium carbonate and copper powder. 10-Phenylphenothiazine (m.p. 94.5-95.5°, prepared from iodobenzene), 10-(*p*-biphenyl)phenothiazine (m.p. 174-178°, prepared from *p*-bromobiphenyl), *p*-bis(10-phenothiazinyl)benzene (m.p. 253-255°, prepared from *p*-diiodobenzene), 10-(2-pyridyl)phenothiazine (m.p. 109-110°, prepared from 2-bromopyridine), and 10-(2-quinolyl)phenothiazine (m.p. 126-128°, prepared from 2-chloroquinoline) were obtained in yields of 77 per cent, 57.5 per cent, 70 per cent, 62 per cent, and 43 per cent, in that order.

p,p'-Bis(10-phenothiazinyl)biphenyl was prepared in a similar manner from *p,p'*-dibromobiphenyl to give material decomposing at 300° (18 per cent). This could not be purified satisfactorily. An attempt to make 10-[4-(7-chloroquinolyl)]-phenothiazine from 4,7-dichloroquinoline was unsuccessful due to the excessive sublimation of the halogen compound during heating.

Boron trifluoride complexes of phenothiazine and 10-(2-pyridyl)phenothiazine were prepared by treating the parent compound with boron fluoride ethyl ether in benzene. The first of these was quite unstable to atmospheric conditions and melted at 158-160° while the second one was quite stable and melted at 305-310°. The exact yields were not determined in either case.

Many of the N-substituted phenothiazines were oxidized to the sulfoxides and sulfones using 30 per cent hydrogen peroxide in refluxing ethanol for the former and 30 per cent hydrogen peroxide in hot glacial acetic acid for the latter. In the preparation of the monoxides a higher concentration of reactants than has been reported previously (6) was found to be of value. 10-(*n*-Decyl)- (m.p. 97-98°, 93 per cent), 10-ethyl- (m.p. 161-162°, 97 per cent), 10-(*n*-octadecyl)- (m.p. 95-96°, 96 per cent), 10-(2-pyridyl)- (m.p. 158.5-159.5°, 69 per cent), and 10-phenylphenothiazine-5-oxide (m.p. 172-173°, 100 per cent) were prepared.

The sulfones of each of these compounds were also prepared with the following melting points and yields being obtained: 10-(*n*-decyl)- (95.5-96.5°, 67 per cent), 10-ethyl- (m.p. 161-162°, 80 per cent), 10-(*n*-octadecyl)- (93-93.5°, 91.5 per cent), 10-phenyl- (211-211.5°, 87 per cent), and 10-(2-pyridyl)- (180-181°, 57 per cent). This last compound was prepared by reduction of 10-(2-pyridyl)phenothiazine-1',5,5-trioxide using iron in hot glacial acetic acid. The trioxide (m.p. 232.5-234°) was initially formed in 80 per cent yield by oxidizing 10-(2-pyridyl)phenothiazine with 30 per cent hydrogen peroxide in glacial acetic acid using the method employed by Ochiai (7) for the preparation of pyridine-1-oxide.

Some nuclear substituted phenothiazine derivatives were also prepared. These include 3-chloro-10-ethylphenothiazine (m.p. 116-117°, 81 per cent) and 3-bromo-10-ethylphenothiazine (m.p. 123-124°, 80 per cent) prepared by the reductive halogenation (8) of 10-ethylphenothiazine-5-oxide using hydrochloric acid and hydrobromic acid, respectively. When 10-(*n*-decyl)-phenothiazine-5-oxide was treated with aqueous hydrochloric acid in a similar way, a 6 per cent yield of impure 3-chloro-10-(*n*-decyl)phenothiazine (m.p. 153-163°) was obtained. This could not be purified further.

10-Ethyl- (180.5-181.5°, 55 per cent) and 10-(*n*-decyl)-phenothiazine-4-carboxylic acid (m.p. 128-129°, 32 per cent) were prepared by the reductive metalation with *n*-butyllithium of the appropriate N-substituted-5-oxide followed by carbonation. The *n*-decyl derivative was also converted to the sodium salt (m.p. 253-254°). The attempts to prepare 10-ethylphenothiazine-4-boronic acid and 4-triphenylsilyl-10-ethylphenothiazine from 4-lithio-10-ethylphenothiazine by reaction with tri-*n*-butyl borate or triphenylchlorosilane were unsuccessful. Likewise, the attempts to prepare the corresponding 3-substituted derivatives were unsuccessful. For these, 3-lithio-10-ethylphenothiazine was treated with tri-*n*-butyl borate and 3-bromo-10-ethylphenothiazine was treated with triphenylsilyl potassium.

The use of *n*-butyl alcohol as a catalyst in the metalation of 10-ethylphenothiazine was found to be of no value.

All of the phenothiazine derivatives that were tested as liquid solution scintillators (1) had a value of 0.12 or less as compared to a value of 1 for the standard, 2,5-diphenyloxazole. These were measured in toluene using a concentration of 3.0 g/liter. Those tested were 10-phenyl-, 10-allyl-, 10-(2-pyridyl)phenothiazine and *p*-bis(10-phenothiazinyl)benzene; 10-phenylphenothiazine-5-oxide and -5,5-dioxide; and 10-(2-pyridyl)phenothiazine-5-oxide, -5,5-dioxide, and -1',5,5-trioxide.

Several simple boronic acids were prepared by treating the organolithium compound with tri-*n*-butyl borate. *o*-Hydroxybenzeneboronic acid anhydride (m.p. 180-183°, prepared from *o*-bromophenol), *m*-hydroxybenzeneboronic acid anhydride (m.p. 215-225° dec., prepared from *m*-bromophenol), 2-hydroxy-5-naphthaleneboronic acid (m.p. 225-250°, prepared from 6-bromo-2-naphthol) and *p*-dimethylaminobenzeneboronic acid anhydride (m.p. 230-275°, prepared from *p*-bromodimethylaniline) were obtained in yields of 55.5 per cent, 31 per cent, 44 per cent, and 30 per cent, respectively. *n*-Butyllithium was used in all of these experiments except the last which employed lithium. An attempt to prepare *m*-hydroxybenzeneboronic acid anhydride from 2-(*m*-bromophenoxy)tetrahydropyran (b.p. 115°/0.4 mm, n_D^{20} 1.5504, d_4^{20} 1.3952, prepared from *m*-bromophenol and dihydropyran in 75 per cent yield) with *n*-butyllithium and tri-*n*-butyl borate was unsuccessful.

When *o*-bromodimethylaniline was treated with lithium and then tri-*n*-butyl borate a compound melting at 85-87° and believed to be a complex between dimethylaniline and boric acid resulted.

1-Butaneboronic acid (m.p. 90-92°) was prepared in 60 per cent yield following an established method (9).

The *o*-hydroxybenzeneboronic acid anhydride was coupled with a number of diazonium salts to give azo boronic acids. 2-Hydroxy-5-(*p*-bromophenylazo)-benzeneboronic acid anhydride (m.p. 350-355°, prepared from *p*-bromoaniline), 2-hydroxy-5-(*o*-nitrophenylazo)benzeneboronic acid anhydride (m.p. 228-230°, prepared from *o*-nitroaniline) and 2-hydroxy-5-(phenylazo)benzeneboronic acid anhydride (m.p. 236-238°, prepared from aniline) were obtained in yields of 20 per cent, 19.5 per cent, and 31 per cent, respectively. Purification was best accomplished by recrystallization from ethylene chloride. The dye, *p*-(3-borono-4-hydroxyphenylazo)benzoic acid, made by coupling *o*-hydroxybenzeneboronic acid anhydride with diazotized *p*-aminobenzoic acid could not be purified successfully. The dye made from diazotized sulfanilic acid and *o*-hydroxybenzeneboronic acid anhydride was crystallized from water to give a material melting above 400° which has not been definitely characterized.

The cleavage of benzeneboronic acid with *n*-butyllithium followed by carbonation gave either 1-butaneboronic acid, benzene, or benzoic acid depending upon the temperature of the reaction. When the reaction was run at either room temperature or reflux for 20 minutes, 1-butaneboronic acid and benzene were isolated. When the reaction was run at -60° for 25 minutes, benzoic acid and an unidentified product were obtained. When a 1.5-hour reaction time at reflux was used, nothing could be isolated.

o-Hydroxybenzeneboronic acid anhydride gave salicylic acid and an unidentified material when treated with *n*-butyllithium at room temperature for 20 minutes and then carbonated.

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ETHANOL EXTRACTION OF COTTONSEED¹

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One of the reasons the solvent extraction industry has not developed in Asiatic countries like India, China, and Japan, which produce enormous amounts of oilseeds, is the difficulty of obtaining a suitable solvent at a cheap price. The conventional petroleum and other solvents have to be imported and therefore become extremely costly due to high import duties and transit charges. The best way out appears to be the use of an indigenous solvent, which could be obtained cheaply.

Among the solvents produced in plenty in Asia is ethyl alcohol, which is available at about half the price of the imported solvents. It is known to be a good solvent for vegetable oils and is bound to become a very popular solvent in Asiatic countries if an economical process for its use is worked out.

Solubility data available in literature are quite favorable for the use of aqueous ethanol as a solvent for extracting all of the commonly used vegetable oils like corn, cottonseed, peanut, sesame, and soybean oils. However, this project pertains to the study of cottonseed oil extraction only.

The main objectives of the project were to determine the feasibility of extracting cottonseed directly using aqueous ethanol as a solvent; to test the adaptability of the Iowa State College extractor for the above purpose and to devise necessary modifications to it; to determine the optimum operating conditions for the alcoholic extraction of cottonseed; and to evaluate the economics of the process.

Laboratory extraction rate studies were carried out in a glass apparatus to determine the effect of temperature, moisture content of flakes, and the effect of temperature, moisture content of flakes, and the concentration of aqueous ethanol on the residual extractables for the extraction of cottonseed flakes by aqueous ethanol.

Pilot plant extractions of cottonseed flakes by aqueous ethanol were carried out in a small unit, similar to the commercial soybean oil extraction plant developed and patented by Iowa State College, to determine the effects of operating variables and the optimum operating conditions.

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Both laboratory and pilot plant extraction studies have shown that direct extraction of cottonseed using aqueous ethanol as a solvent is a feasible process and the optimum operating conditions for it have been established in the pilot plant unit.

Based on the results obtained in the pilot plant, it appears likely that the present Iowa State College extractor can be adopted, with some modifications, for the ethanol extraction of cottonseed. These modifications are discussed.

Pilot plant extractions have shown that in this process a prime quality crude oil and light colored meal of excellent quality with negligible free gossypol content are obtained.

Based on the data available in literature an economic cost study for a 50-ton-per-day commercial plant indicated an annual return on investment of 8.7 per cent.

CHEMICAL EFFECTS OF PHOTONUCLEAR REACTIONS IN THE PROPYL BROMIDES¹

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In the field of research involving the chemical effects of nuclear reactions, more commonly known as "hot-atom" chemistry, there have been relatively few investigations comparing the effects which result from different nuclear reactions in a given system. In the present work chemical effects resulting from photonuclear reactions in the propyl bromides have been observed and compared with those resulting from the (n, γ) and isomeric transition modes of activation.

In order to obtain reproducible results in liquid irradiations it has been necessary to slightly extend previously reported purification techniques. Such techniques, which have been designed to remove slight traces of olefinic impurities, did not appear adequate for the purpose in the present studies. An extra step, in which bromine was added to the propyl bromide and the mixture allowed to stand overnight, seemed to remove the last traces of olefins.

The 65 Mev Iowa State College synchrotron was the source of the high energy γ -rays used. Propyl bromide samples were irradiated in a Pyrex tube which was immersed in a Dewar flask. The irradiation temperature could be controlled by the addition of the appropriate liquid or liquid-solid mixture to the Dewar.

The x-ray fluxes associated with these γ -rays were in the range of 300 to 1000 roentgens per minute, but several aspects of the data appear to discount any appreciable radiation damage. Work of other investigators has shown that the fluxes involved in the present investigation should not cause a noticeable amount of radiation damage in the propyl bromides.

After irradiation the propyl bromide was shaken with an aqueous Na_2SO_3 solution containing small amounts of NaBr and H_3AsO_4 as carriers for the bromine and arsenic activities produced by photonuclear reactions on bromine. In the shaking process all inorganic bromine was extracted into the aqueous layer, while the organically bound bromine was left behind in the propyl bromide layer. The resulting aqueous and organic samples were counted to determine the total organic retention.

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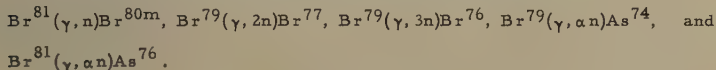
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When it was desired to determine relative yields of various organic products containing radioactive bromine, a portion of the propyl bromide from which the inorganic bromine had been extracted was added to a mixture of seven compounds ranging in complexity from ethyl bromide to trimethylene bromide. These compounds were then fractionally distilled in a five-foot helix-packed distillation column. The higher boiling compounds were taken over at reduced pressures. The column proved adequate to separate enough of each compound for counting in better than 95 per cent purity. All counting was done in liquid G.M. counting tubes with 5 to 7 ml annular jackets. The counting rates of various samples were corrected for radioactive decay and liquid density and the percentage yields were calculated.

Five radionuclides have been observed in the present investigation. These are produced by the following nuclear reactions:



Gross curves were analyzed into the above component activities. The photo-nuclear reactions to produce Br^{77} and Br^{76} have not previously been reported in the literature. The reaction $\text{Br}^{81}(\gamma, \alpha)\text{As}^{77}$ which was previously reported was not here observed.

Four (γ, n) runs on liquid n-propyl bromide which had been extensively purified gave a Br^{80m} retention of 47.4 ± 0.9 per cent, compared to a Br^{80m} retention of 34 per cent by (n, γ) activation. The (γ, n) value for iso-propyl bromide was 36 per cent which is higher than the reported 30 per cent (n, γ) retention value. The $(\gamma, n)\text{Br}^{80m}$ retentions in solid n-propyl and iso-propyl bromides at -196°C were found to be 85 and 96 per cent, respectively, compared to the respective values of 78 and 83 per cent previously reported for the $(n, \gamma)\text{Br}^{80m}$ reaction. These solid state results are in opposition to the initial recoil energy hypothesis postulated by Libby and coworkers.

The scavenging effects of bromine and α, β -dibromoethylene which were noted in liquid n-propyl bromide for the $\text{Br}^{81}(\gamma, n)\text{Br}^{80m}$ mode of activation indicate a breakdown of reactions as follows: 25 per cent, nonthermal organic; 22 per cent, thermal organic; 28 per cent, thermal inorganic; and 25 per cent, nonthermal inorganic. The respective values for the (n, γ) reaction have been reported to be 22, 12, 26, and 40 per cent.

Scavenger effects seem also to have occurred in crystalline propyl bromides at -196°C , providing evidence that thermal reactions occur in the pseudo-liquid volume which is produced in the solid around the recoil atom as it loses its energy to the solid medium.

Irradiated samples of the propyl bromides were fractionally distilled to determine the percentage yields of many of the organic products formed as a result of the photonuclear production of Br^{80m} . The yields in the solid state show a very striking similarity to those for the $\text{Br}^{81}(n, \gamma)\text{Br}^{82}$ activation. In the liquid state there are noticeable increases in yields of compounds as the result of the breakage of C-C bonds and in the yield of propylene bromide. The yield of parent compound in liquid n-propyl bromide containing 4.7 mole per cent added Br_2 is only 8.8 per cent compared to a yield of 19.8 per cent in pure n-propyl bromide, which indicates that a large proportion of the parent compound is formed by thermal reactions. In the presence of Br_2 as a free radical scavenger very striking agreement was observed between (γ, n) and (n, γ) activation indicating among other things that the much greater energy of recoil atoms following the (γ, n) reaction does not increase the yield of the parent compound.

The ratio of parent compound yield to total organic yield in liquid n-propyl bromide was found to be very nearly the same for Br^{76} and Br^{80m} . Elastic collision mechanisms to produce the parent compound should result in a smaller ratio for Br^{76} than for Br^{80m} .

Analysis of decay curves resulting from γ -irradiation of solid n-propyl bromide at -196°C into $\text{Br}^{80\text{m}}$, Br^{76} , and Br^{77} activities allowed the calculation of retention values which were respectively, 87 per cent, 67 per cent, and 62 per cent. The large difference in the values for $\text{Br}^{80\text{m}}$ and Br^{76} indicates some isotope effect. The values, however, represent the results of only a single run and could be in error. The fact of importance here is that the curves can be analyzed, thus making such retention calculations possible. It is hoped that future investigators will check these values.

The above results, in general, indicate some new ideas about the mechanism by which $\text{Br}^{80\text{m}}$ atoms re-enter combination. It appears that the initial recoil energy is unimportant in determining yields, except in the greater production of radicals. The random fragmentation theory of Willard seems to be favored by the very close similarity of percentage yields for the (γ, n) and (n, γ) modes of activation. To be more explicit one might say that the relative yields of organic products are based mainly on the probabilities for the random formation of each. Elastic collision mechanisms at energies above 10 ev to produce the parent compound are not important, and probably contribute to not more than about 3 per cent of the total retention.

The greater production of radicals which occurs as a result of higher energy recoil atoms or as the result of a change of state from liquid to solid probably enhances retention for two main reasons. (1) Breakage of C-C bonds produces organic radicals but not inorganic ones; and (2) H atoms, which are the primary inorganic radicals, will diffuse away much faster than their organic counterparts. Both of these factors would increase the probability of a recoil atom being captured by an organic radical and thus increase the retention.

The reasons for isotope effects are not clear from the data which have thus far been obtained. The relative diffusion rates for the various isotopes may be important. Delayed γ 's resulting in bond rupture after a recoil atom has recombined may also explain retention differences for various isotopes. The investigations of these aspects of the field should prove quite useful in gaining a better understanding of the various mechanisms by which recoil atoms re-enter combination.

A THEORETICAL STUDY OF THE ELECTRONIC STRUCTURE OF TRANSITION-METAL COMPLEXES¹

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Among the many interesting chemical and physical properties of transition-metal ions is their curious ability to exhibit two different magnetic moments when combined with various ligand groups. The existing hybrid orbital treatment of these transition-metal complexes correlates the experimentally measured magnetic moments with the bond character between metal and ligand; that is, those complexes with the smaller moment are classed as covalent, using, e.g., $3d^2 4s 4p^3$ octahedral hybrid metal orbitals; those with the higher moment are classed as ionic. A more recent suggestion is that ionic complexes make use of certain high energy ("outer d") orbitals of the metal in

¹Doctoral thesis number 1834, submitted August 7, 1956.

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forming, e.g., $4s4p^34d^2$ octahedral hybrids. As a pure theory, the hybrid orbital treatment is deficient in this application, since its essential ingredients are derived only from experiment.

In direct contrast is the purely theoretical crystalline field approach, wherein the ligands are reduced to sets of point charges and dipoles and the chemical bonding effects are explicitly ignored. This theory gives a qualitatively correct interpretation of most observed physical properties; but even when adjustable parameters are introduced, it has been found impossible to produce quantitative agreement between theory and experiment without taking into account chemical bonding effects.

A simple molecular orbital (MO) picture of these complexes has been advanced to reconcile the disparities between the crystalline field and the hybrid orbital approaches. In addition, the MO theory combines the computational features of the first with the empirical and conceptual advantages of the second. It is the purpose of this thesis to extend this simple MO theory by making detailed quantum mechanical computations upon the electronic structures of two complex ions, FeF_6^{3-} and $\text{Fe}(\text{NH}_3)_6^{3+}$. Two objectives were in mind: first, to investigate the practicality of applying modern chemical valence theories, in semi-empirical form, to quite complicated electronic systems; and second, to interpret the results of such a calculation in as general a fashion as possible, so that the conclusions can be extended to other transition-metal complexes.

In order to pursue the problem further, it was deemed necessary to devise better metal atomic orbitals than those afforded by the usual Slater approximations. These better orbitals were obtained by a systematic curve-fitting technique utilizing the few Hartree functions available in this region of the periodic table.

A semiempirical theory was devised, based upon Roothaan's self-consistent field MO computational procedures and Mulliken's approximations for certain molecular integrals. Only valence-shell atomic orbitals were used in constructing MO's and all one-center integrals were approximated in terms of valence-state ionization potentials. Exchange integrals were included in proper form; since there are five unpaired electrons in the complexes considered, differentiation was made between MO's for electrons with positive spin and those for electrons with negative spin.

In the calculations for the ammonia complex, there existed some uncertainty about the description of the lone-pair electrons on the ammonia molecule. Two possibilities were considered, namely that the lone-pair electrons were either in a tetrahedral or in a $2s$ nitrogen atomic orbital. Neither case produced a satisfactory result; inspection of the problem suggested that one probable contributor to the discrepancy was that the assumed metal to nitrogen distance (1.92 \AA) is too short; there exists some crystallographic evidence that this distance should indeed be greater.

The calculated results for the fluoride complex were much more satisfactory, both the predicted visible spectrum and the unpaired electron density distribution being in reasonable agreement with comparable experimental conclusions. According to the calculations, even in as "ionic" a complex as the ferrifluoride ion is presumed to be, about 35 per cent of the unpaired electron density is delocalized from the metal ion, in striking contradiction with the assumption of crystalline field theory.

Analysis of the factors which determine the magnetic and spectral properties, as well as many of the chemical properties, reveals that the electrostatic effects, assumed to be of direct importance in the crystalline field theory, actually are of much more subtle influence.

Rather, the results of this study indicate that there are two other factors of comparable importance, the first of these stems from the overlap of the metal and ligand orbitals, as expressed in the requirement that all wave functions of the complex ion must be orthogonal. This important restriction has been neglected in other current work on this subject, with the result that an important feature of the metal-ligand interaction has been overlooked. The

second factor is the probable importance of the outer (extra-valence shell) orbitals, not only of the metal but of the ligand as well, in more precisely determining the energies and distributions of the magnetic electrons in all classes of complexes. This factor is difficult to measure, due to uncertain knowledge of these outer orbitals. Nevertheless, at least qualitative consideration appears necessary.

These two factors tend to cancel one another, so that in a number of cases their combined effect is roughly the same magnitude as that arising from the coulomb factor. However, when the ligand is a neutral group, the electrostatic effect is much the smaller.

As a final conclusion to this work, it is believed that the present theory is sufficient to define the general nature of the various metal-ligand interactions and the comparative magnitudes of the quantities involved. Hence, major profit is expected from continuing similar theoretical calculations which suggest new and useful experiments as well as provide a more detailed insight into existing experimental data.

A CONCEPTUAL VARIABLE ANALYSIS OF TECHNOLOGICAL CHANGE¹

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The relationships among six conceptual variables and a dependent conceptual variable, technological change, were analyzed by means of the statistical method of multiple regression. The concept of technological change is defined as the degree to which an individual accepts or adopts new technological ideas or practices. An adoption of farm practices scale was constructed to operationally measure the concept of technological change.

Six independent conceptual variables were analyzed as they related to technological change: change orientation, communication competence, status achievement, cohesion with the locality group, family integration, and cohesion with the kinship group.

Change orientation is defined as the degree to which an individual possesses a favorable attitude toward technological changes. A change orientation index was constructed to operationally measure the concept of change orientation.

Communication competence is defined as the degree to which an individual regards as credible the more technically accurate sources of information. Status achievement is defined as the degree to which an individual has achieved high social status in the social system. Indexes were constructed to measure both the concepts of communication competence and status achievement.

The concept of cohesion is defined as the degree to which an individual accepts the roles prescribed by a reference group. An extra-locality orientation index was constructed to measure the concept of cohesion in the locality group. An index of kinship orientation was constructed to measure the concept of cohesion with the kinship group.

The concept of family integration is defined as the degree to which an individual is oriented toward optimizing rewards and satisfactions for other family members. The family integration index was developed to measure the concept of family integration.

¹Doctoral thesis number 1894, submitted March 12, 1957. Chairman of Committee, George M. Beal, Department of Economics and Sociology.

²B.S., Iowa State College, Ames. M.S., *ibid.*
Associate, Agricultural Experiment Station.

One of the purposes of the study was to determine the extent to which technological change might be predicted from the six independent variables. Almost 17 per cent of the variation in the adoption of farm practices scale, measuring the concept of technological change, was explained by the variation in the six independent variables.

Another purpose of the present study was to determine which conceptual variables are the best predictors of technological change. Relationships significantly different from zero were found between technological change and the concepts of change orientation, communication competence, and status achievement. Relationships not significantly different from zero were found between technological change and the concepts of locality group cohesion, family integration, and kinship group cohesion.

When the effect of the other five independent variables were controlled by partial correlation techniques, relationships significantly different from zero were found between technological change and the concepts of change orientation, communication competence, and status achievement. Relationships not significantly different from zero existed between technological change and locality group cohesion, family integration, and kinship group cohesion.

The prediction equation was computed from which the degree of technological change for an individual might best be predicted from his scores on the six independent conceptual variables.

Other sociological concepts and improved operational measures of sociological concepts which might be employed in future research endeavors to predict technological change were suggested. An interdisciplinary approach to the study of technological change was proposed that would include economics, psychology, education, and journalism, in addition to sociology.

THE EFFECT OF GRINDING ON THE ACIDULATION OF PHOSPHATE ROCK¹

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An investigation was undertaken to determine the effect of grinding on the acidulation of phosphate rock. Bench-scale work was carried out in a one quart, laboratory ball mill made of stainless steel. The mill was equipped with a heating chamber so that the material could also be dried in the mill.

The results from this work indicated that a normal superphosphate product suitable for commercial use could be obtained within an hour after the addition of the first acid. The product had low moisture and low free acid contents, and under suitable conditions, granular form. The mixing action of the balls resulted in good heat transfer during drying with little danger of overheating the product. Consequently, the drying air temperature had little effect on the product except in the rate of production. The reaction was sufficiently rapid in the mill so that no preliminary grinding period was necessary before the drying operation was started. Low acidulation ratios resulted in low conversions as in any normal superphosphate process. Low acid concentrations were more conducive to a rapid reaction between the rock and acid. Below an acid strength of about 55 per cent, however, there was no further advantage in dilution.

¹Doctoral thesis number 1924, submitted June 5, 1957. Chairman of Committee, D.R. Boylan, Department of Chemical Engineering.

²B.S., Michigan College of Mining and Technology, Houghton. M.S., *ibid*. Graduate Assistant, Engineering Experiment Station.

The favorable results of the bench-scale work led to the construction of a pilot plant to determine whether the process could be carried out on a larger scale and on a continuous basis. The process was built around a heated tube mill with a stainless steel lining and a feeding mechanism. Heating was indirect. The acid and rock were fed into one end of the mill and product taken from the other.

Successful pilot plant operation showed that the bench-scale results could be duplicated on a larger scale and on a continuous or semicontinuous basis. Furthermore, it was demonstrated that the materials could be handled satisfactorily in the tube mill. Plugging and other difficulties were overcome.

Finally, an economic comparison of the process with an equivalent, standard, normal superphosphate process indicated that the quick-curing process was favored. Fixed capital, production cost, and working capital were estimated to be less than for a conventional, normal, superphosphate process. The estimated return on investment for a conventional plant was 3.8 per cent while the equivalent quick-curing plant gave an estimated 5.6 per cent.

DEHYDROGENATION STUDIES IN THE FIELD OF INDOLE ALKALOIDS¹

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Various methods of dehydrogenation have been used in the field of indole alkaloids, but no concentrated effort has so far been made to obtain some information about their preparative and stereochemically diagnostic value. The stereochemistry of the reductive processes used for regeneration of the alkaloids from their dehydro derivatives also has not been fully studied.

Among the dehydrogenation methods already in use, two methods were investigated extensively. The first one, dehydrogenation by palladium-maleic acid (1), was used for ring C dehydrogenation of compounds containing various substituents in ring E. It was also observed that this type of dehydrogenation of epiallo compounds proceeds at an appreciably slower rate than that of their pseudo analogues. On the basis of this observation, 3-isoajmalicine and akuammigine were classified as epiallo and pseudo products, respectively. Tetrahydroakuammigine perchlorate was shown to be identical with alstonine perchlorate.

Thus, ajmalicine possesses an allo structure and tetrahydroalstonine a normal structure, akuammigine being the latter's 3-isoderivative. Consequently also, serpentine (tetrahydroajmalicine) possesses a D/E cis configuration and alstonine can be represented by a D/E trans stereof ormula.

The second method, oxidation by mercuric acetate (2), produced 3-dehydro derivatives of the alkaloids.

Both dehydrogenation methods yielded 5,6-dehydrosempervirine from $\Delta^{15}(20)$ yohimbene, the latter being obtained by sodium borohydride reduction of sempervirine (3).

Catalytic hydrogenation and sodium borohydride reduction of tetrahydro and 3-dehydro compounds regenerated exclusively their normal and allo precursors. Reduction of 3-dehydro normal systems by zinc and glacial acetic acid yielded appreciable amounts of pseudo compounds along with the corresponding normal derivatives.

¹Doctoral thesis number 1888, submitted March 11, 1957.

Chairman of Committee, Ernest Wenkert, Department of Chemistry.

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The spectral region of the C-H stretching vibration, $3.4\text{--}3.7\mu$ in the infra-red, was used to identify the stereo-configuration of the hydrogen atom at C_3 of the alkaloids or their derivatives. All compounds possessing an α hydrogen at C_3 , i.e., normal and allo products, exhibited two or more distinct peaks on the high-wavelength side of the major 3.46μ band, whereas those compounds containing a C_3 -H β -orientation, i.e., pseudo and epiallo products, showed merely shoulders on the high-wavelength side of the main peak.

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A COMPARISON OF MICROSPOROGENESIS
IN FERTILE AND STERILE POTATO VARIETIES¹

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Flower development and the morphology of microsporogenesis was studied in Katahdin, a pollen fertile potato variety; Sebago, a partially pollen fertile variety; and B 595-76, a pollen sterile selection.

Flower development in the potato is similar to that found in the tomato. The flower arises as a small rounded mass of cells. The calyx develops as a five-lobed marginal ring enclosing a broad convex receptacle. The stamens and petals appear simultaneously as upright lobes from the margin of the receptacle. The five petals alternate with the calyx segments, and the stamens alternate with the petals. A central vascular strand extends the complete length of the stamens and calyx.

The sporogenous tissue appears in the anthers at an early stage and is recognized as a horseshoe-shaped area very clearly marked off from the surrounding tissue. Palisade-type tapetal cells are found on the outside of the area. On the inside of the sporogenous tissue are found large vacuolated cells that form the inner tapetum.

The sporogenous cells increase in size, lose much of their angular shape and are then recognized as the pollen mother cells. They give rise to the pollen grains by a reductional and equational division occurring in rapid succession. The microspores increase in size, develop thick walls and become the pollen grains.

During microsporogenesis in Katahdin, the cells of the inner and outer tapetal layers are multinucleate and filled with cytoplasm. Vacuoles are found in the cells of the inner tapetum. The pollen mother cells remain distended with protoplasm and stain lightly.

Many of the inner tapetal cells of Sebago are slightly plasmolyzed before microsporogenesis. The outer tapetal layer and microsporocytes are not visibly effected.

Microsporogenesis in B 595-76 is characterized by the plasmolyzed, dark

¹Doctoral thesis number 1896, submitted March 14, 1957.

Chairman of Committee, August E. Kehr, Department of Horticulture.

²B.Sc., University of Idaho, Moscow. M.S., Iowa State College, Ames.
Associate, Agricultural Experiment Station.

staining cytoplasm of the pollen mother cells and by the plasmolyzed appearance of the large cells that make up the inner tapetum. Plasmolysis does not prevent meiosis but the microspores produced are large, fragile, and probably nonviable.

It is postulated that a nutritional deficiency caused by high temperature exists within the anthers that affects both the cells of the inner tapetum and the pollen mother cells of the varieties B 595-76 and Sebago. The difference in degree of plasmolysis existing in the pollen mother cells of the two varieties could result in complete pollen sterility in B 595-76 and a very low pollen fertility in Sebago.

DEVELOPMENT OF THE PROTECTIVE STRUCTURES OF THE PLANT EPIDERMIS¹

Robert Harold Schieferstein²

Department of Botany and Plant Pathology

The use of agricultural chemicals that must gain entrance into the plant leaf to be effective has renewed scientific interest in plant cuticles. These surface coverings, being lipid in nature, restrict water loss from leaves and may also restrict entry of agricultural chemicals. The aims of this research were to determine how the cuticle was expanded during growth of the leaf, to determine the nature and extent of secondary cuticle thickening, and to gain some insight into how these and other factors may influence the permeability of cuticle to water and to 2,4-dichlorophenoxyacetic acid (2,4-D)

The evidence obtained supported the hypothesis that the cuticles of leaves which had a rapid rate of expansion were extended at unhardened zones near the margins of individual epidermal cells during growth of the leaf. Electron microscope examination showed that the cuticle of corn in the zone at the borders of epidermal cells had an appearance very much like that of young leaves still encased in the coleoptile; but dewaxed, mature leaves of corn had a much different surface appearance. When surface wax was wiped from expanding leaves of corn and *Nicotiana glauca*, electron micrographs of replicas of the surface made two to six days later showed that surface wax was restricted to bands that outlined the individual epidermal cells. Presumably the wax was replaced selectively on the newly formed areas of cuticle. On cabbage leaves wax was replaced over the entire surface. Immature appearing cell border zones were found on ten species which had rapidly expanding leaves. On three xerophytic species where the leaves or organs expand very slowly no border zones were found.

It was demonstrated that even on herbaceous, annual leaves secondary cuticle thickening may proceed to such an extent that the cuticle becomes anchored directly in the cellulose of the outer wall of epidermal cells. Ethanolamine, a pectin solvent, removed the cuticle from cabbage leaves of all ages except the oldest which were just beginning to turn yellow with age. Cellulose was detected in enzymically isolated cuticle samples from mature leaves of nine species that may be considered xerophytic or somewhat xerophytic. Cuticle samples from one nonxerophytic species contained cellulose and samples from two others did not.

¹Doctoral thesis number 1923, submitted June 4, 1957. Chairman of Committee, Frederick G. Smith, Department of Botany and Plant Pathology.

²B.S., Oregon State College, Corvallis. M.S., Iowa State College, Ames. Associate, Agricultural Experiment Station.

The amount of cuticular wax per unit area was found to be correlated with the degree to which plants could withstand dry habitats for three species that ranged from a mesophyte to an extreme xerophyte. No such correlation was obtained for amount of surface wax. Wax deposition varied with age for the different species. Surface wax deposition, where present, usually ceased with termination of leaf expansion or shortly afterward. Cuticular wax deposition usually continued for a longer period.

Swelling of enzymically isolated cuticular preparations upon water saturation and shrinking upon drying demonstrated that even the lipid materials that form the cuticle are somewhat polar. Observations on the direction of curl of cuticle preparations upon wetting and drying indicated that the preparations were less polar near the outer surface and more polar in inner portions.

Stomateless cuticular preparations from the upper surface of ivy leaf had 1.44 ± 0.14 times the permeability to water in the inward direction compared with the outward direction. This may be considered further evidence that the preparations were less polar on the outer surface. Permeability in the outward direction varied only slightly with age and averaged $0.214 \text{ mg/cm}^2/\text{hr}$ at 25°C .

A spectrophotometric method was developed that enabled the determination of amounts of penetration of 2,4-D as low as $0.002 \text{ micromoles/cm}^2$. The rate of penetration through ivy cuticular preparations varied considerably with the age of the leaf and hence the thickness of the cuticle. The thinnest preparations from leaves that were just fully expanded gave penetration rates from a 0.1 molar solution averaging $0.0764 \text{ micromoles/cm}^2/\text{hr}$ at room temperature, and the thickest from leaves just under three years old gave rates averaging $0.0018 \text{ micromoles/cm}^2/\text{hr}$. The relative penetration rate at different cuticle thicknesses indicated that thickness was not the only factor involved in permeability to 2,4-D. The system developed for this study would be adapted to the investigation of several factors that may influence the rate of penetration of 2,4-D.

SYNTHESIS OF RADIOACTIVE PIPERONYL BUTOXIDE AND ITS METABOLISM IN THE MADEIRA ROACH, *LEUCOPHAEA MADERAE* (F.)¹

Claude Henri Schmidt²

Department of Zoology and Entomology

Piperonyl butoxide is one of the important insecticide synergists used with pyrethrins. As an aid to studying its mode of action in insects, radioactive piperonyl butoxide, α -[2-(2-n-butoxyethoxy)-ethoxy]-4,5-methylenedioxy-2-propyltoluene- $\alpha\text{-C}^{14}$, was prepared by reacting C^{14} -labeled paraformaldehyde with dihydrosafrole then condensing the resulting chloromethyl derivative of dihydrosafrole with the sodium salt of diethylene glycol n-butyl ether. The radioactive product purified by vacuum distillation was identical to a non-radioactive standard as determined by ultraviolet, infrared, colorimetric, and chromatographic analyses. Ultraviolet and infrared absorption spectra of these compounds are shown. The over-all yield was 61 per cent based on C^{14} -paraformaldehyde. The radioactive piperonyl butoxide had a counting rate of $155 \text{ cpm}/\mu\text{g}$ as measured on a Nuclear Model D-46A gas flow counter and a

¹Doctoral thesis number 1833, submitted August 7, 1956. Chairman of Committee, Paul A. Dahm, Department of Zoology and Entomology.

²B.A., Stanford University, Palo Alto, California. M.A., *ibid*.
Graduate Assistant, Agricultural Experiment Station.

specific activity of 0.157 $\mu\text{C}/\text{mg}$. The feasibility of using aqueous formaldehyde instead of paraformaldehyde for the synthesis of piperonyl butoxide was investigated.

For the paper chromatographic analysis of piperonyl butoxide, acetonitrile-methanol-water, 2:2:1 (v/v), was used as the solvent system. Three different procedures for locating piperonyl butoxide on paper chromatograms are described in addition to the radioactive scanning technique. Two procedures can be used on chromatograms containing over 50 μg of piperonyl butoxide; either spraying with one of two dyes, D and C Violet No. 2 or D and C Red No. 18, or by streaking with concentrated sulfuric acid. For smaller amounts of piperonyl butoxide, both an ultraviolet scanning technique based on absorption at 290 $\text{m}\mu$, and a radioactive scanning method using a "micromil" window Geiger-Mueller tube, Nuclear Model D-47, were useful.

The effect of organic solvents on the Blum* colorimetric test for piperonyl butoxide was investigated. The absorption spectra of the colored complexes formed by these solvents are presented. The selection of a solvent was important; acetone, carbon tetrachloride, and methyl ethyl ketone produced more intense color complexes and n-hexane, Skelly B, and benzene gave less intense colors than did acetonitrile, the solvent recommended in the Blum procedure.

The absorption and excretion of radioactive piperonyl butoxide was studied following topical application to male and female Madeira roaches, *Leucophaea maderae* (F.). About 88 per cent of the piperonyl butoxide was absorbed in 3 days; about 50 per cent of the radioactivity in the applied dose was recovered over a 7-day period from feces extracted with 80 per cent acetone. Paper chromatographic analysis of fecal extracts showed that less than 50 per cent of the radioactivity in the feces was piperonyl butoxide, the remainder consisted of unidentified water-soluble metabolites. The internal distribution of radioactivity 24 and 48 hours after topical application of C^{14} -labeled piperonyl butoxide to female roaches showed that the brain and thoracic ganglia, fore-gut and hind-gut including Malpighian tubules contained the greatest amount of radioactivity per unit weight. Since little radioactivity was found in the other tissues of the roach, it is postulated that the nervous tissue, fore-gut and hind-gut, and Malpighian tubules are involved in the breakdown and excretion of radioactive piperonyl butoxide in the Madeira roach.

This investigation was made possible by grants-in-aid from the United States Atomic Energy Commission, Contract No. AT(11-1)-59 and from the Fairfield Chemical Division of Food Machinery and Chemical Corporation, Baltimore 3, Maryland.

*Blum, M.S. 1955. Colorimetric determination of small quantities of methylenedioxyphenyl-containing pyrethrum synergists. Jour. Agric. Food Chem. 3:122-124.

APPLICATION OF INPUT-OUTPUT ANALYSIS TO A
REGIONAL MODEL STRESSING AGRICULTURE¹John Alvin Schnittker²

Department of Economics and Sociology

Input-output analysis has two distinct aspects. It is both a method of describing trade relationships among sectors of an economy, and a means of projecting past relationships to future situations. The input-output technique was used as the basis for construction of a model of the United States economy for 1949. Objectives were to estimate relationships between agricultural regions, and between agricultural regions and the rest of the economy. Since agriculture was of primary interest, aggregation of the agricultural economy, and of industrial processes closely related to agriculture, was at a lower level than aggregation of other industrial processes. Also agricultural production was divided regionally, based on type-of-farming areas.

Estimates of trade patterns in agricultural products between regions of the United States and between agricultural producers in different regions and national industries were made. Lack of data caused many revisions in concept, and required rough estimates of sector relationships in many cases.

Trade patterns among producing sectors, and between producing and consuming sectors of the national economy, were estimated and shown in monetary terms in a transactions matrix. Input coefficients, describing in ratio form the relationship between the net output of a producing sector j and the fraction of the output of sector i which was consigned to sector j , were computed from transactions data. These ratios are the coefficients of a system of equations describing the final demand for the products of any sector as a function of the net outputs of all producing sectors and the flows of products between producing sectors of the economy.

Estimation of the transactions data and computation of the input coefficients constitute an intermediate stage in the study. Preceding sections describe inferences which can be drawn using these data. The transactions matrix gives a perspective of the trade patterns of the entire economy. The input coefficients facilitate estimates of direct effects of increased net output of a sector upon other sectors supplying its inputs. All agricultural sectors were seen to have depended heavily upon industry sectors for their inputs in 1949. Industry sectors were less dependent upon agriculture for their inputs. Also, interregional differences existed in the agriculture-industry interrelationships.

The inverse of the input coefficient matrix was used to describe the net outputs of each sector as a function of the parts of the final bill of goods. Models of the economy were constructed in which foreign trade and government were considered (a) as intermediate sectors, and (b) as final demand sectors. Interdependence coefficients computed were similar under the two procedures. Also, estimates of changes in net outputs, given changes in final demand were similar for situations (a) and (b), above. Little importance is attached to the interdependence coefficients in this study. Changes in agricultural final demand entries have negligible effects upon the net outputs of the other sectors of the economy.

Hypothetical changes in final demand for the products of food processing industries appear to have a realistic basis. Even there, differential changes in the demand for various kinds of foods are beyond the scope of the input-output model. Yet, these are the kinds of demand changes currently observed and predicted for the future.

¹Doctoral thesis number 1829, submitted July 23, 1956. Chairman of Committee, Earl O. Heady, Department of Economics and Sociology.

²B.S., Kansas State College, Manhattan. M.S., *ibid.*
Associate, Agricultural Experiment Station.

The volume of data required for the input-output or transactions matrix is prohibitive if considerable disaggregation of the economy is desired. Since so many flow estimates are required, the investigator must constantly compromise his desire to make accurate estimate, with the need to make a great volume of estimates in a given time. It was seen early in this study that there is implicit in each estimate of an intersector transaction, one or more research projects of the "partial" type disparaged by the enthusiasts for input-output analysis.

Some of the estimates in the transactions matrix were made fairly directly. Others, such as the product flows from the machinery industry to agricultural sectors, were made from a complex set of data from different sources. These data had to be reduced to comparable form, and assigned to agricultural regions or to commodity producing sectors of agricultural regions. Other estimates, like cattle shipments, could not be made at all with the resources of this study. Considerable effort was spent in preliminary research, in order to discover the data shortages. Revisions in concept were made where data problems were insurmountable.

The experience in this study confirmed the experience or the preconceptions of many of the critics of input-output analysis. As a descriptive technique, it has value in providing insights into the workings of a complex economy. Its descriptive content is converted to very crude analytical use by computation of the technical coefficients of production. But use of these production coefficients to compute interdependence coefficients for further use in projection, appears to be worthwhile in models similar to this one only if the inverse matrix can be computed relatively cheaply, as was the case here.

Use of funds for construction of models of the economy and computation of interdependence coefficients, can be justified only by expectations of results more valuable than those likely from other analytical techniques. Despite the appeal of the generality of the input-output system, its high cost will continue to be a barrier to use by many research workers. Even heavier drains upon research funds would be inevitable if complex experiments were undertaken to check the accuracy of the production functions implicit in input-output tables.

TOXICITY OF SOME ORGANIC ACARICIDES TO MITES
INFESTING APPLE AND CHRYSANTHEMUM¹John Theodore Schultz²

Department of Zoology and Entomology

Investigations of phytophagous mites infesting apple and chrysanthemum disclosed two species to have predominated in the Iowa orchards under observation, Tetranychus telarius (L.), the two-spotted mite, and Metatetranychus ulmi (Koch), the European red mite. Of lesser importance, but occasionally found in numbers was Bryobia praetiosa Koch, the clover mite.

A quadrant sampling method was employed for the determination of infestation intensity, and M. ulmi was found to have favored north- and east-facing portions of the tree in early season counts. Preference for these sectors by M. ulmi was not exhibited in mid or late season evaluations. This preference did not hold for T. telarius, which was found in almost equal numbers throughout the four sectors during the season.

Because of the developmental cycles of the two major species, it was found necessary to initiate the spraying program between June 15 and July 1 to effectively control infestations of M. ulmi. Two applications, ten days apart, were necessary to achieve lasting commercial control. A third application of Chlorobenzilate and malathion was warranted in order to control infestations of M. ulmi. Two applications, ten days apart, were necessary to achieve lasting commercial control. A third application of Chlorobenzilate and malathion was warranted in order to control infestations of T. telarius which reached peak concentrations in July. In three years of evaluation of acaricides in orchards, the following gave the best control.

Systox, 6 ounces actual toxicant, controlled infestations of M. ulmi better than those of T. telarius.

Trithion, 0.25 pound actual toxicant, and Kelthane, 1.5 pints of the 25 per cent emulsifiable concentrate in 100 gallons of spray dilution, controlled infestations of T. telarius better than those of M. ulmi.

In response to the repeated use of chlorinated and organic phosphate compounds, a slight tolerance to acaricides, Chlorobenzilate and malathion, was evidenced in one orchard under study in 1956. In a second orchard, where mites were known to be parathion resistant, control with chlorinated compounds, Kelthane and Chlorobenzilate, was not a problem in 1956.

Evaluations of systemic organic phosphate acaricides on chrysanthemum showed T. telarius best controlled with Systox and Thimet. By electrometric analyses of residues, the lethal level for T. telarius, following Systox applications, was about 20 ppm of Systox and metabolites; following Thimet, 200 ppm of Thimet and metabolites.

Studies of methods of application of Systox and Thimet, and of host and mite response to them, indicated the soil drench and granulated applications superior in having given the longest period of control of T. telarius, namely 56 days following the soil drench, 30 days following the granulated applications.

Phytotoxicity was expressed by the chrysanthemum following both methods of application, even to the lowest dosages tested (Thimet, 0.25 pound actual toxicant, Systox, 6 ounces actual toxicant).

Use of present day systemic phosphate applied as foliar sprays, granules, and soil drenches watered into the soil, has not given control of T. telarius in blossoms of chrysanthemum.

¹Doctoral thesis number 1910, submitted May 24, 1957. Chairman of Committee, H.M. Harris, Department of Zoology and Entomology.

²B.S., Iowa State College, Ames. M.S., *ibid*.

Graduate Assistant, Agricultural Experiment Station.

CROSS SECTION OF THE $\text{Ca}^{40}(\gamma, 3p3n)\text{Cl}^{34}$ REACTION¹Fritz Duane Schupp²

Department of Chemistry

The cross section of the $\text{Ca}^{40}(\gamma, 3p3n)\text{Cl}^{34}$ reaction as a function of photon energy was determined by radiochemical techniques up to 70 Mev with the Iowa State College synchrotron. With the use of the theoretical bremsstrahlung spectra, the intensity of the X-ray beam was experimentally calibrated by three methods:

1. Known cross section function of the $\text{Cu}^{63}(\gamma, n)\text{Cu}^{62}$ reaction
2. Ionization produced in an air cavity in paraffin and its calculated response
3. Calorimetrically calibrated ionization chamber.

The cross section function was observed to be resonant shaped with its peak at 50 Mev and with a width at half the maximum of 6 Mev. The magnitude of the cross section at its maximum by the above methods of flux calibration are:

1. 0.29, 0.37 millibarn^{3,4}
2. 0.41 millibarn
3. 0.25 millibarn.

Good agreement was obtained between the cross section function of the $\text{Ca}^{40}(\gamma, 3p3n)\text{Cl}^{34}$ reaction from the ionization measured in an air cavity in paraffin and the function from the comparison to the copper reaction similarly determined⁴. There was agreement between the calorimetric method and the method utilizing the more recent copper cross section function³ which had been obtained from an external electron beam and the theoretical cross section for the bremsstrahlung process. The values obtained by the calorimetrically calibrated ionization chamber and the more recent copper cross section function³ are considered to be more accurate than the others.

Agreement of the cross section functions of the $\text{Ca}^{40}(\gamma, 3p3n)\text{Cl}^{34}$ reaction obtained by the $\text{Cu}^{63}(\gamma, n)\text{Cu}^{62}$ cross section functions below 23 Mev with the calorimetric and ionization methods indicates the copper cross section function is not appreciable in the energy range of these experiments.

The most likely mode of the $\text{Ca}^{40}(\gamma, 3p3n)\text{Cl}^{34}$ reaction on the basis of threshold considerations and the relative reaction probability calculated by a statistical model is $(\gamma, \alpha 2n)$ to A^{34} which would decay by rapid positron emission to Cl^{34} .

The significance of the requirements for a hydrodynamic nuclear model were discussed for the formation of a compound nucleus for the photoexcitation of Ca^{40} and in terms of a statistical model for the reactions leading to Cl^{34} from the compound system.

¹Doctoral thesis number 1871, submitted December 13, 1956.

Chairman of Committee, Don S. Martin, Department of Chemistry.

²B.S., Missouri Valley College, Marshall, Missouri.

Research Assistant, Institute for Atomic Research.

³Using the copper cross section function determined by M.B. Scott, A.O. Hanson, and D.W. Kerst, *Phys. Rev.* **100**:209, 1955.

⁴Using the copper cross section by L. Katz and A.G.W. Cameron, *Can. Jour. Phys.* **29**:518, 1951.

APPLICATION OF LINEAR PROGRAMMING FOR PROFIT
MAXIMIZATION IN THE FEED FIRM¹J. T. Scott²

Department of Economics and Sociology

The study represents an application of linear programming for profit maximization in an individual feed manufacturing company. The specific objectives were: (1) to determine what formulas a feed company should produce and sell; and (2) to determine the most profitable volume for each of these formulas. In addition there were two sub-objectives. One sub-objective was to find whether workable and realistic information could be prepared with the use of firm records and managerial estimates. The other was to obtain the answers to the specific objectives at the lowest practical cost in order to estimate the economic feasibility of the actual use of the linear programming technique by operating feed firms.

The firm selected for the study was a typical feed company. It owned no retail outlets and had only one plant which produced and sold 42 mixed feeds and merchandised three ingredients. Ingredients were purchased from suppliers in several states but sales were made almost entirely in Iowa where the company merchandised to hatcheries and elevator and farm supply businesses.

The principle followed in the collection of data was that no information would be used which was not readily available to management. It was felt that if linear programming was to be a workable tool of feed firms, it would ordinarily have to be based on about the same quality of information now used. For this reason the data used in the program were, in part, subjective judgments of management.

After programming computations were completed and the most profitable plan discovered, a comparison of 1955-56 firm operations was made with those called for by the program. Net profit for the program was \$31,414.36 and for 1955-56 it was \$15,418.74. Thus, it was found that the sales called for under the program would provide \$15,995.62 more net profit than 1955-56 sales.

The program also increased the quantity of total sales by 12,599 fifty-pound bags over the 1955-56 sales level. Two groupings were made of the products by the company in an effort to see which groups of feed and program increased over their 1955-56 level.

In one grouping it was found that poultry feeds increased 19 per cent over the 1955-56 level. Hog feed sales increased 3 per cent, beef feed sales decreased 33 per cent, dairy feed sales increased 42 per cent, and other feed and product sales decreased 8 per cent.

The other classification of feeds showed an eight per cent increase in complete feeds, miscellaneous products a ten per cent increase, and pre-mixes and concentrates a nine per cent increase in sales over the 1955-56 sales. High molasses products showed the most decisive change in sales. This group showed 100 per cent decrease in sales from the 1955-56 sales level.

The restriction which curtailed expansion of profits most drastically was salesman hours. The firm operating under the program could have made \$25.20 more net profit if there had been another hour of sales contact at no additional cost. If they could have bought this additional hour for \$20.20 they could have added \$5.00 to net profits.

¹Doctoral thesis number 1920, submitted June 4, 1957. Chairman of Committee, Richard Phillips, Department of Economics and Sociology.

²B.A., Louisiana Polytechnic Institute, Ruston. M.B.A., University of Arkansas, Fayetteville. Associate, Agricultural Experiment Station.

The coefficients and restrictions provided by management are not precise; therefore the solution to the program cannot be used as a formula to higher profits. The author feels, however, that management can use this analysis with a fair degree of confidence provided common sense is used in interpreting the results.

The cost of computation using the short-cut solution as employed in this dissertation would not be too expensive, especially after a person gained facility in the use of the method. It would appear, however, that the higher costs of electronic computers might not be justified for small feed firms. Large companies might benefit enough from the program that they could pay the higher price on problems which could not be solved by the short-cut method.

CHOICE OF CROP ROTATIONS UNDER CROP-SHARE LEASES: A LINEAR PROGRAMMING APPLICATION¹

James Arthur Seagraves²

Department of Economics and Sociology

Principles of production economics were used to explain some fundamental theories about the economics of crop rotations and about crop-share leasing. Hypotheses about the optimum choice of products and fertilizer levels were developed from these theories and from observations about crop-share leasing in Northern Iowa. The hypotheses dealt with the level of cash-rent for pasture, with the sharing of fertilizer costs, and with the efficiency of leases which share all crops and operating expenses in the same proportions.

Experimental data for six crop rotations with four fertility treatments for Nicollet and Webster soils of Northern Iowa were used, together with assumptions about techniques and prices, to establish budgets for 24 activities. Linear programming was applied to choose the maximum profit programs for crop-share tenants and landlords under eight hypothetical leases. The leases provided tests of the hypotheses.

Labor and capital resources of the tenant and landlord were varied in order to show whether these hypotheses apply to a variety of resource situations. Resource situations also were assumed for an owner-operator who had the combined capital of the landlord and tenant.

A lease was considered efficient if the optimum productive programs of the tenant, landlord, and owner-operator were identical. No single lease met this standard for all resource situations; however, all except two in which fertilizer and seed costs were not shared met it when capital was unlimited.

The \$8 per acre cash rent for cropland in pasture, which was common in Northern Iowa between 1949 and 1953, was too low to provide maximum agreement among landlord, tenant, and owner-operator. When each leasing party had very limited amounts of capital available an \$8-\$16 cash rent was indicated. However, with less limiting capital the tenant desired more land in pasture than the landlord at even a \$25 per acre rent. The indications were that cash rent should be considered a variable factor when leases are designed and renewed.

Agreement was virtually impossible among the tenant, landlord, and owner-operator when the tenant paid all the fertilizer costs and received only a share

¹Doctoral thesis number 1874, Submitted December 14, 1956. Chairman of Committee, Earl O. Heady, Department of Economics and Sociology.

²B.A., Reed College, Portland, Oregon. M.S., Iowa State College, Ames. Graduate Assistant, Department of Economics and Sociology.

of the added returns from fertilizer. Leases like those typical in Northern Iowa, in which only fertilizer and several other variable costs were sometimes shared, were not a satisfactory answer because they led to an overuse of fertilizer by the tenant. It was seen that complete sharing of all variable expenses in the same proportion guarantees an optimum allocation of fertilizer but at the same time gives rise to some additional problems.

Leases which shared all crops and all expenses in equal proportions provided perfect agreement among the landlord, tenant, and owner-operator when the leasing parties had identical resource limitations. However, agreement was far from perfect when the landlord did not assume the labor limitations of the tenant and when their capital limitations were different. It was noted that complete share leases resemble a partnership, and like this, depend upon a close decision-making relationship between the leasing parties. While complete share leases solve the problem of the allocation of inputs like fertilizer, they intensify the problems of providing incentives for tenant labor.

The results of this study suggested the following things with respect to crop-share leases in Northern Iowa: (1) Higher cash rents for cropland in pasture are indicated, and \$25 per acre is not too high in some cases. (2) The sharing of fertilizer and seed costs appears to be very important to their efficient allocation, and it is anticipated that the sharing of several other variable expenses such as the costs of weed and insect control and gleaning is necessary to their optimum use. (3) There is no indication that a lease which shares all variable expenses and all crops in the same proportion would provide more agreement among the optimum programs of the landlord, tenant, and owner-operator than would the typical crop-share lease now in effect in Northern Iowa if a higher cash rent for pasture were added. (4) The best lease in terms of agreement among the tenant, landlord, and owner-operator depends upon the resource limitations of the leasing parties.

A PROCESS FOR SEPARATING THORIUM COMPOUNDS FROM MONAZITE SANDS¹

Kernal Glenn Shaw²

Department of Chemical Engineering

The purpose of this investigation was to study the sulfuric acid digestion of monazite sand, and to prepare a thorium-containing material from the resulting solution which would be suitable for further purification by liquid-liquid extraction. It was also desired that the by-product rare earths and uranium be recovered in a form convenient for further processing.

Studies were made in the laboratory and in a pilot plant to determine the optimum conditions for the digestion of monazite sand and for the separation of thorium, rare earths, and uranium by fractional neutralization of the monazite sulfate solution. The most effective separation was obtained when the monazite solution was dilute and when ammonium hydroxide was used as a neutralizing agent. The resulting process consisted of the following steps:

1. Digestion of fround monazite sand in 93 per cent sulfuric acid for five hours at 155-230°C. The acid-to-sand weight ratio was 1.56.

¹Doctoral thesis number 1425, submitted June 8, 1953.

Chairman of Committee, Morton Smutz, Department of Chemical Engineering.

²B.S., (Science) Pennsylvania State College, University Park. 1947.

B.S., (Chemical Engineering) *ibid.* 1948.

Research Assistant, Ames Laboratory of the Atomic Energy Commission.

2. Dissolution of the solid reaction products in water and clarification of the solution by allowing the acid-insoluble sludge to settle.

3. Fractional precipitation of thorium phosphate by dilution of the monazite sulfate solution with six parts of water and neutralization to a pH of 1.05 with ammonium hydroxide.

4. Fractional precipitation of the rare earth phosphates by neutralization of the filtrate from the thorium separation to a pH of 2.3 with ammonium hydroxide.

5. Fractional precipitation of uranium phosphate and the remainder of the rare earths by neutralization of the filtrate from the rare earth separation to a pH of 6.0 with ammonium hydroxide.

The precipitates from each fraction were thickened and filtered. The over-all recovery of thorium was 96-97 per cent, of rare earths 98-99 per cent, and of uranium 53-54 per cent. The remainder of the thorium and uranium can be recovered by further processing.

A cost comparison was made between the Ames Laboratory process and a process developed by the Battelle Memorial Institute for a plant which would produce five tons of thorium per month from Idaho monazite sand. The estimated processing cost for the Ames Laboratory process was \$9.11 per pound of thorium as compared with \$11.48 per pound for the Battelle process. Both of these costs included \$4.67 for the cost of the monazite sand. The Battelle caustic digestion process produced two hydroxide concentrates. One contained thorium and uranium. The other contained rare earths. Hydroxide concentrates could also be produced by the Ames Laboratory Process by a caustic digestion of the three phosphate concentrates at an additional cost of about \$1.25.

ANILINE-FURFURAL STABILIZATION OF IOWA LOESS¹

John Briggs Sheeler²

Departments of Chemical Engineering and of Civil Engineering

Natural gravel sources in southwestern Iowa and in other areas in the United States are being rapidly depleted due to extensive secondary road construction and maintenance. The loess deposits of southwestern Iowa are very extensive and offer a possibility as a road building material. However, the soil must be suitably stabilized before all-weather roads can be constructed from this material.

The primary objectives of this investigation have been to establish and evaluate the best methods for stabilizing Iowa loess with aniline-furfural resin. The research has been carried on in conjunction with an over-all research project investigating the properties and stabilization methods for Iowa soils. This project is being carried on under contract with Iowa State Highway Commission and under sponsorship of the Iowa Highway Research Board and is supported by funds supplied by the Commission and the U.S. Bureau of Public Roads.

The investigation indicates that the optimum moisture-density relationship of aniline-furfural stabilized soils should be determined for every proposed

¹Doctoral thesis number 1839, submitted August 13, 1956.

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soil and that aniline and furfural cannot be regarded as liquids that replace equal volumes of water for density requirements.

A mol ratio of 2 mols aniline to 1 mol of furfural produced the best results while weight ratios anywhere between 3:2 and 5:2 may be used without excessive loss of effectiveness. Water and furfural should be mixed with the soil first to obtain the best results.

Drying is nearly complete after five days of air curing and strengths have reached a near final value after four days. However, 10 days of air curing are necessary for equilibrium conditions to be well established.

Small quantities of aniline-furfural reduce the dry strength of treated soil but any addition of the resin increases the wet strength. The wet strength of aniline-furfural stabilized loess exhibits a maximum value at about 22 per cent clay content for any constant amount of resin treatment.

Even the lowest resin treatment imparts a significant waterproofing to the loess. Treated specimens are very resistant to artificial laboratory weathering. Aniline-furfural treatment shows evidence of being beneficial to the all-weather stability of Iowa loess.

AVAILABILITY OF RESIDUAL FERTILIZER PHOSPHORUS AND ITS EVALUATION IN IOWA SOILS¹

Charles Mortimer Smith²

Department of Agronomy

The objectives of this investigation were to study the effects of single or multiple applications of phosphorus fertilizer in different years on the availability of the residual phosphorus resulting therefrom, and to compare chemical soil test, crop yield, crop composition, and radioactive A value measurements as methods for measuring the residual effects on these and previously established experiments.

Three field experiments were initiated in the spring of 1953. Two were located on acid Floyd and Edina silt loam soils and one on a calcareous Ida silt loam soil. Phosphorus applications were made over a 3-year period for the purpose of establishing levels of residual phosphorus resulting from different times of application. Oats were grown each year, since it was believed a shallow rooted, short season crop should be used to minimize the removal of phosphorus during the early stages of the experiment and to minimize the dilution effect of phosphorus absorbed from below the fertilizer zone on the correlations of field and other measurements. Grain yields and total plant phosphorus absorption were measured each year.

In the spring of 1955, soil samples were collected from the experiments and were used for chemical and greenhouse tests. The latter included plant growth measurements and radioactive measurements, utilized as A values. The soil samples were taken with a large sampling tube and consisted of approximately 60 cores per plot of 60 square feet. This thorough sampling was made for the purpose of insuring representative values for correlation studies with field data.

Greenhouse A values were used as the criterion for evaluating the other

¹Doctoral thesis number 1880, submitted December 19, 1956.

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measurements. Significant correlation coefficients were obtained for comparisons with field A values, yield of phosphorus in the field and greenhouse, and soil test phosphorus.

The relationship between soil test phosphorus and greenhouse A values for the acid Floyd and Edina silt loam soils was described by a single regression line. The chemical soil test predicted greenhouse A values equally well for the one- and two-year-old phosphorus applications. Results of comparisons in 1954 involving these measurements on soil samples from 14 old experiments, containing levels of residual phosphorus, also indicated a single regression line. Similar results were obtained on 1953 samples. The regression of soil test phosphorus on greenhouse A value measurements for the calcareous Ida silt loam soil, however, described a line with a significantly smaller regression coefficient. This effect was probably caused by the free CaCO_3 in the soil.

Significant correlations were obtained when the chemical soil test results were compared with other criteria including yield of phosphorus in the field and greenhouse, and field A values. A contributing factor may have been the detailed soil sampling technique employed. Several of the methods were satisfactory for measuring the effects of residual phosphorus; however, its simplicity and high degree of correlation with greenhouse A values makes the chemical soil test particularly useful.

The field results obtained from the experiments on the two acid soils generally indicated similar trends. Grain and total phosphorus yields indicated both in 1954 and 1955 that current applications of phosphorus were significantly better than previous applications. There was little evidence on either soil to indicate that the residual value of a given rate of phosphorus fertilizer was enhanced by splitting the application.

The results of the calcareous Ida silt loam soil indicated that a current application of concentrated superphosphate produced lower yield increases than a like amount applied one or two years previously. Evidence was presented that indicated a lack of uniformity in the mixing of the current application with soil to the depth of plowing, which in dry weather could result in a reduction in the effectiveness of the current phosphorus applications. A test was made that indicated differences between years of application could not be attributed to differences in the effectiveness of unit quantity of phosphorus absorbed in promoting biological response. Therefore, there was no indication of a difference in availability resulting from a change in the chemical nature of the phosphorus. Differences observed between measurements of the availability of one- and two-year-old applications were not significant.

The regression of greenhouse A values on rates of applied phosphorus was linear for the acid soils and at the higher levels of phosphorus for the calcareous soil. Employing greenhouse A values as criteria and the assumptions that the absorption of native soil phosphorus was constant at different levels of residual fertilizer phosphorus and that a current application of phosphorus was 100 per cent effective, the percentage effectiveness of residual phosphorus from applications made one and two years previously, relative to current applications on the Floyd, Edina, and Ida silt loam soils was on the order of 55 to 57, 68 to 75, and 65 to 75, respectively. Computations made in a similar way for the other soils sampled indicated that most of them fell into a range of 40 to 65 per cent effectiveness for one and two-year-old applications and 20 to 40 per cent for three-year-old applications.

CRYSTAL PHYSICS OF SILVER PERCHLORATE-BENZENE
COMPLEX AND METAL WHISKERS¹Harold Glenn Smith²

Department of Physics

Part I. Structure and Lattice Energy of the Silver Perchlorate-Benzene Complex.

The structure of the silver perchlorate-benzene complex has been accurately determined by a three-dimensional least squares analysis. The silver ions are displaced 0.26 Å from the mirror planes of the space group Cmc_m in a disordered manner. This results in unequal Ag-C distances for a given benzene ring. They are 2.496 ± 0.006 Å and 2.634 ± 0.008 Å. Three of the Ag-O distances are 2.68 ± 0.02 Å and one is 3.20 ± 0.01 Å.

The benzene ring itself is distorted from hexagonal symmetry; the C₂-C₂ and C₁-C₂ distances are 1.354 ± 0.017 Å and 1.427 ± 0.010 Å, respectively; the angles C₁-C₂-C₂ and C₂-C₁-C₂ are 122.2° and 115.7°, respectively.

The oxygen atoms of the perchlorate ion are also displaced slightly off the mirror planes but this is probably a measure of the anisotropy of the thermal motion of the ion. The chlorine-oxygen bond distances are 1.444 ± 0.018 Å for Cl-O₁ and 1.508 ± 0.009 Å for Cl-O₂. The O₁-Cl-O₁ and O₂-Cl-O₂ angles are 106.3° and 113.2°, respectively.

Calculations showed that the lattice energy of the cubic structure of silver perchlorate is 165.0 kcal/mole; the lattice energy of silver perchlorate expanded to the volume of the benzene complex is 127.0 kcal/mole. It was found that the induction energy of benzene due to the ion-induced dipoles in the benzene complex is 12.4 kcal/mole. The van der Waals energy of benzene in the complex is estimated to be 6.8 kcal/mole. The energy due to charge-transfer forces between a silver ion and one benzene molecule is 15.7 kcal/mole. The polarizability of the perchlorate ion was also calculated, and the average value is 4.65 Å^3 .

Part II. X-ray Investigation of Tin Whiskers.

The X-ray diffraction data were obtained by photographic and Geiger counter methods using MoK_α and CuK_α radiation, respectively. It was necessary to use the dynamical theory of X-ray diffraction to explain the observed data. The agreement is very good for a crystallite size of 1.5μ for a 5.5μ whisker and 2.7μ for whiskers about 10μ in diameter. This indicates the whiskers are not perfect crystals although they exhibit a higher degree of perfection than is usually attributed to bulk specimens in general.

The lattice constants, $a_0 = 5.820 \pm 0.001 \text{ kX}$, $c_0 = 3.18 \pm 0.01 \text{ kX}$, are in agreement with those reported for pure tin within experimental error. The various colors reflected from the faces of the crystals are attributed to thin films (presumably tin oxide) on the whisker surfaces.

The Debye characteristic temperature calculated from the X-ray data, $\theta = 126^\circ$, is nearly the same as that determined from low-temperature specific heat data, $\theta = 130^\circ$, but is not in agreement with the very-low-temperature ($1.2 - 4.5^\circ \text{K}$) value, $\theta = 195^\circ$. The last value is in agreement with the Debye temperature obtained from elasticity data assuming a simple Debye solid.

¹Doctoral thesis number 1908, submitted May 10, 1957.

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MOVEMENT OF WATER IN UNSATURATED SOILS¹Karl Ralph Stockinger²

Department of Agronomy

Two phases of the problem of movement of water in unsaturated soils were studied. One phase dealt with a method of determining the capillary conductivity of soil as a function of the soil moisture tension. The other phase dealt with infiltration of water into soils.

To determine the capillary conductivity of the soil, a vertical tube of soil with water supplied freely at zero pressure at the lower end and evaporated from the upper end was allowed to reach a steady state condition. The hydraulic head was measured at various points along the tube by means of tensiometers made from sintered glass sealing tubes. The rate of flow was measured and the pressure of the water at the lower end of the tube was controlled by means of a burette which operated like a Mariotte bottle. An empirical function

$$\phi = ae^x x^b + c + dx$$

where

x = the ratio of the height of the observation to the length of the tube

d = the hydraulic head necessary to move the steady state flow rate through the soil tube if it were saturated

was found which could be fitted to the hydraulic head data by adjusting the values of a , b , and c to be measured values of d , x , and ϕ by the method of least squares. The function was differentiated to give the hydraulic gradient which was then used with the rate of flow in the Darcy equation to give the capillary conductivity as a function of the parameter x . The moisture tension was also expressed in terms of the parameter x by adding a term xL , for height, to the right hand side of the equation for ϕ , where L is the length of the tube.

The above procedure was used to determine the capillary conductivity of disturbed samples of Edina silt loam and Marshall silt loam. The results for any one soil were quite variable. However, the capillary conductivity for all trials showed a similar pattern. The soil maintained the conductivity of a saturated soil until the moisture tension exceeded a critical value determined by the pore geometry. At this point some pores were no longer filled and the conductivity rapidly decreased with increasing tension to values of less than one per cent of the saturated conductivity for moisture tensions of 30 cm and approached a zero conductivity asymptotically. The chief difference in the soils was the rapidity of the decrease of conductivity after the soils were no longer saturated, being more rapid for the Marshall than the Edina soil.

The results were used to compute the length of tube necessary to carry out a similar experiment with an equal flow rate in the horizontal direction. It was found that a tube of soil 30 meters long would be necessary for such a flow rate to develop a moisture tension of 50 centimeters at the end. The moisture tension as a function of the height was calculated for two flow rates and used to illustrate the mode with which water would be supplied to plants by a water table.

¹Doctoral thesis number 1902, submitted April 12, 1957.

Chairman of Committee, Don Kirkham, Department of Agronomy.

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Graduate Assistant, Agricultural Experiment Station.

For the infiltration phase of the study samples of three soils from the desert regions of Arizona and California ranging from a loamy sand to a silty clay were used. Tubes of soil were prepared from the air-dried disturbed samples in such a manner to be as uniform as possible. The tubes were placed horizontally or vertically and connected to a source of water which maintained a constant head of zero. The amount of water entering as a function of time was recorded. The equation

$$Q = at^b + c$$

where

Q = total amount of water absorbed

t = time

was found to describe the total amount of water absorbed for the horizontal tubes. The constants a , b , and c of this equation were fitted to the observed values of Q and t by the method of least squares.

According to Poiseuille's law the exponent b should be $1/2$. This was true for the lighter soils but the clay soil gave a mean value of 0.645 which was found to be significantly different from the predicted value of $1/2$. This variation of the exponent appears to be related to the structural stability of the soil.

It was found that the addition of a linear term dt , d being a constant, to the equation for horizontal flow resulted in an equation which fit the vertical flow data almost perfectly. Thus the equation for infiltration, i , was

$$i = at^b + dt + c.$$

The constants were fitted to the data by the method of least squares and it was shown that the value of a was not different for the horizontal or vertical case. Other tests indicated that the constant d varied as the sine of the angle the tube makes with the horizontal and thus verified the gravitational nature of the linear added term. Practical examples of the use of the infiltration equation were discussed.

IMPROVED INSTRUMENTATION AND SOME OPERATIONAL
PRINCIPLES FOR THE NEUTRON MODERATION METHOD
OF MEASURING SOIL MOISTURE¹

John Floyd Stone²

Department of Agronomy

A fieldworthy neutron moderation soil moisture meter is described. This device is comprised of a probe unit and a counting unit. The probe unit consists of a special probe carrying case and a probe. The carrying case provides a radiation shield for the operator when the probe is being carried about. The radiation shield is made of lead and paraffin. The paraffin serves not only to shield the operator from fast neutrons, but serves also as a standard hydrogenous medium for standardization of readings. The probe itself is two inches in diameter and contains a detector for slow neutrons (B 10 lined detector) and a source of fast neutrons (10 mc. Ra-Be). Also included in the probe is a pulse amplifier which will operate into any reasonable length of coaxial cable (a 50-foot length has been tried with no noticeable pulse attenuation). The neutron source is of annular shape and is placed about the geometrical center of the counter tube. The counting unit employs decade counting, glow transfer tubes. Dry batteries are used for power supply. The whole device weighs 40 pounds. The instrument can be safely used 8 hours a day, 6 days a week.

Experiments show that the standard error of the mean for moisture readings is one-sixth the standard error of the mean for moisture determinations made gravimetrically (using a Veihmeyer sampling tube). The standard error of the mean for a single profile reading for measuring the water in a field plot 20 feet wide and 40 feet long to a 5-foot depth seems to be 0.07 inches of water. This includes variations due to the soil, Colo silty clay loam. Typical field data obtained in an evapotranspiration experiment are also given.

A set of instructions is given for construction, operation, and repair of the device. Assembly diagrams and electronic diagrams are presented.

Measurement and calibration procedures are given by which certain sources of error, such as battery drift, counter circuit dead time and background count, are minimized. Equations are given by which the magnitude of these errors can be readily determined. A method is described for laboratory calibration using mixtures consisting of sand and a hydrated salt, aluminum ammonium, and sulfate.

In the method for measuring soil moisture by neutron moderation, a slow neutron distribution arises, due primarily to soil moisture, in the vicinity of a source of fast neutrons placed in or next to moist soil. Existing theoretical expressions for the distribution for moderated neutrons in a system indicate that there is a dependence upon, among other things, the neutron macroscopic scattering cross section of the medium. This cross section is, in turn, dependent upon several factors, one of which is the atomic-densities (numbers at atoms per unit volume) of the several types of elements present. Therefore, for a given soil type, this cross section should vary with bulk density.

Readings were made in small containers, in the laboratory, with the probe of the soil moisture meter. The containers were filled with various mixtures using sand, water, and crystals of alum. These readings confirmed for a given hydrogen density that the slow neutron flux sensed by the detector in the probe is dependent upon the amount of material contributing to the macro-

¹Doctoral thesis number 1921, submitted June 4, 1957.

Chairman of Committee, Don Kirkham, Department of Agronomy.

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scopic scattering cross section of the medium. The laboratory results are in qualitative agreement with a theory which, in turn, indicates that the effect of the macroscopic scattering cross section upon the slow neutron distribution could be less pronounced in a very large medium. Despite the foregoing, research workers have not found sufficiently marked effects of bulk density to include the bulk density of soil in calibration procedures for the neutron method. The bulk density effects have probably not been included because they are difficult to measure in field soils where sampling errors and natural variability in composition mask density effects. Also field measurements are often made at low moisture contents when bulk density effects on neutron moderation are, the experiments show, small. Although, in the field data reported in this dissertation, density effects, if present, have been masked by other factors; it may be that for some soil types the density effect is appreciable. Further work should shed more light on this.

DRIVING EFFICIENCY OVER A SIX-HOUR PERIOD BY SIMULATED DRIVING PERFORMANCE¹

Virtus William Suhr²

Department of Vocational Education

In this investigation driving efficiency was studied over a six-hour period by simulated driving performance. An attempt was made to determine the nature of the performance curve for certain variables amenable to continuous measurement. A series of psychological, physiological, psychometric and psychophysical tests were administered both before and after the driving period in an effort to detect any changes that may have occurred in performance on certain psychophysical characteristics deemed relevant to safe automobile driving. Periodic refreshment pauses were introduced at intervals of 90 minutes and their effect on the onset and extent of work decrement was noted. A personal evaluation protocol was obtained from each participant so that subjective feelings could be compared with driving performance and with other test results.

Two groups of 28 subjects each were used in the study. Each subject was individually taken through an experimental cycle lasting approximately nine hours. The experimental or refreshment-pause group was given a 15-minute rest period during which tea was served with additives as preferred, every one and one-half hours during the experimental procedure as stated. The control or no-pause group received no pause or refreshments. Otherwise the treatments were identical.

A series of psychological, physiological, simulated driving performance, and paper and pencil tests were administered to each driver during the pre-testing period of approximately one and one-half hours. The subjects in the refreshment-pause group were than given refreshments and a rest pause after which they began a period of six hours of simulated driving using the Drivometer which was installed in a special air-conditioned booth at the Driving Research Laboratory, Iowa State College. The no-pause group were taken directly from the pre-testing into the simulated driving phase of the experimental procedure where they did simulative driving for six consecutive hours.

¹Doctoral thesis number 1870, submitted December 13, 1956

Chairman of Committee, A.R. Lauer, Department of Vocational Education.

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Research Associate, Industrial Science Research Institute.

Data were recorded every half hour for the variables that could be subjected to a continuous evaluation. In addition a red stop light was presented on five different occasions not systematically arranged during each half hour of the driving period. The time required for the driver to notice the signal light and respond by depressing the brake pedal was recorded as stop light response time. Also, an electric train was caused to emerge from a tunnel into the view of the driver five times at irregular intervals each half hour. The time required to notice the train and react by depressing the brake pedal was called train reaction time.

Immediately following the six hours of simulated driving, the series of tests which were administered during the pre-testing period were repeated in the same sequence. The experimental cycle was completed by having each driver subjectively evaluate his own level of efficiency by completing a self-evaluation form of 14 items prepared for the purpose.

An analysis of covariance was made of the data gathered from the tests which were administered before and repeated again after the driving period. The initial scores were taken as the covariates.

The discrete data were analyzed by means of the chi-square technique. Two by two contingency tables were constructed. The Yates correction factor was used whenever the frequency in a cell was less than five.

A split-plot analysis was made of the data gathered during the driving period. The group mean scores for each half hour were plotted and graphs constructed.

Each analysis was made three times. First, all 28 subjects in each treatment group were included. Secondly, only the 19 men in each treatment group were considered. A third analysis was made using only the data from the nine women drivers in each treatment group.

The hypothesis tested in this study, stated in the null form is as follows: a 15-minute rest period, during which time tea with additives as preferred is served, every one and one-half hours has no effect on the psychophysical characteristics or on simulated driving performance of automobile drivers.

The hypothesis is rejected for steering score made on the Drivometer when all the subjects considered and also when the men drivers only are considered. The steering score is the number of contacts in the right lane of the traveling roadway that were crossed by the miniature car per period of time. The same is true for steering efficiency or the number of contacts in the right lane of the traveling roadway that were crossed by the miniature car per unit of simulated distance traveled. The refreshment-pause group had a higher average score on both of these variables. The differences were significant at the one per cent level of confidence.

The women drivers in the refreshment-pause group drove a greater simulated distance on the average each half hour than those in the no-pause group. The F-value was significant at the five per cent level of confidence. When the total group was considered and also when the men drivers were considered separately, both the diastolic blood pressure and the number of errors on an attention to detail exercise were significantly lower for the no-pause group. A difference in systolic blood pressure between the women drivers in the two treatment groups was revealed. This difference was significant at the five per cent level of confidence with the no-pause group having the lower pressure.

No differences in the drivers' subjective evaluation of their driving efficiency at the end of the experimental procedure were of sufficient magnitude to be statistically significant. Since some of the objective measures did reveal significant differences between the two treatment groups, it would appear that an individual may have reduced efficiency without being subjectively aware of it.

The general results of the investigation seem to indicate that a periodic refreshment pause is useful in increasing the maximum performance, prolonging efficiency curve and reducing the extent of work decrement particularly in a type of activity simulating road driving performance.

RADICAL REACTIONS OF AROMATIC NITRO COMPOUNDS¹John A. Tanaka²

Department of Chemistry

Part I. The p-Nitrophenylradical substitution on nitrobenzene.

This study was undertaken to broaden our understanding of the mechanism of homolytic aromatic substitution reactions.

The p-nitrophenyl radical was generated by the decomposition of p-nitro-N-nitrosoacetanilide. When this decomposition was carried out in nitrobenzene, the ortho, meta, and para substitution of p-nitrophenyl radical on nitrobenzene gave rise to a mixture of dinitrobiphenyls. The isomer ratios were determined and compared with those reported by other workers. Large amounts of other products were also formed. An azo compound which apparently has three nitro groups and three aromatic rings was isolated as one of these products. There was always some tarry material formed which was not easily eluted from an alumina column. In order to test whether these tars resulted from secondary reactions, 2-deutero-3,4'-dinitrobiphenyl was added to the radical decomposition and the tar tested for deuterium. The very small deuterium content of the tar indicated that dinitrobiphenyls are not a great deal more reactive toward p-nitrophenyl radicals than nitrobenzene.

Part II. Reactivity of triphenylmethyl radical and nitrobenzene.

This investigation was initiated to test the hypothesis that the nitro group of aromatic nitro compounds is involved in radical reactions.

The triphenylmethyl radical in the presence of nitrobenzene was found to be active after a month. Triphenylmethyl radical activity was similarly found after long periods of contact with 1,3,5-trinitrobenzene and nitrosobenzene. No evidence could be obtained for the reduction of the nitro group by the triphenylmethyl radical.

¹Doctoral thesis number 1843, submitted September 10, 1956.

Chairman of Committee, George S. Hammond, Department of Chemistry.

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MAGNETIC PROPERTIES OF Gd-La AND Gd-Y ALLOYS¹Wilbur C. Thoburn²

Department of Physics

Successful methods of temperature control and centering, for a sample whose magnetic moment is to be measured by weighing it in an inhomogeneous field, have been described.

Four alloys of gadolinium with lanthanum, and seven others of gadolinium with yttrium, have been examined for their magnetic properties. Paramagnetic Curie temperatures and Curie constants have been determined for all the alloys, and ferromagnetic Curie points and saturation moments for the six alloys which showed ferromagnetism. Thence the effective atomic moments and the saturation atomic moments, per gadolinium atom, have been computed. Néel points have been determined for those alloys which showed antiferromagnetism.

The four Gd-La alloys show the following results:

1. An alloy of 47 per cent concentration of Gd by atoms is paramagnetic down to 20°K. It has the lattice structure of lanthanum.
2. An alloy having 90 per cent of Gd atoms is ferromagnetic below 258°. It has the structure of gadolinium.
3. Intermediate alloys with 75 and 83 per cent of Gd atoms show antiferromagnetic regions below their poorly defined Néel points, respectively, at about 130° and 155°. Their lattice structure is not clearly defined.

The seven Gd-Y alloys show the following results:

1. All have the gadolinium structure with nearly the same lattice constants.
2. At low temperatures alloys with 25 to 60 per cent of Gd atoms show antiferromagnetism and alloys with 60 to 100 per cent of Gd atoms show ferromagnetism.
3. The paramagnetic Curie temperatures indicate a regular, though not quite linear, dependence on gadolinium content. The plot of θ_p against the content of gadolinium follows a convex curve from an estimated 0°K for pure yttrium to 302.7° for pure gadolinium.
4. A near approach to the same line is made by the Néel points of alloys having less than 50 per cent of Gd atoms, and by the ferromagnetic Curie points of alloys having more than 75 per cent of Gd atoms. In the neighborhood of the composition of 60 per cent of Gd atoms, however, the Néel point and θ_f fall far below the line, particularly the latter. For this composition the antiferromagnetic peak appears only for very weak fields, and its temperature is substantially lowered from its zero-field (197°) as the field is increased.

In general, the effective atomic magnetic moments per gadolinium atom as calculated from the paramagnetic data, and the corresponding saturation atomic moments as calculated from the ferromagnetic data, are somewhat higher than the theoretical values for pure gadolinium. The results indicate a contribution to the magnetic moment from some source not yet clearly understood.

¹Doctoral thesis number 1847, submitted October 23, 1956.

Chairmen of Committee, Sam Legvold, Department of Physics, and F. H. Spedding, Institute for Atomic Research.

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ASPECTS OF THE CAGE EFFECT IN THE DECOMPOSITION OF
AZO-BIS-ISOBUTYRONITRILE¹Orlin Dalton Trapp²

Department of Chemistry

This study was undertaken to broaden the understanding of the cage effect in the free radical decomposition of 2, 2'-azo-bis isobutyronitrile (AIBN).

Dimethyl-N-(2-cyano-2-propyl)-ketenimine was observed as an intermediate in the decomposition of AIBN. This ketenimine can be isolated provided the decomposition of AIBN is carried out in a solvent, such as cyclohexane, in which AIBN and tetramethylsuccinonitrile (TMSN) are very slightly soluble. This intermediate forms and decomposes by consecutive first order reactions.

Decomposition of AIBN in liquid bromine yields no TMSN, the proposed product of nonradical decomposition of AIBN.

That dimethyl-N-(2-cyano-2-propyl)-ketenimine decomposes to give free radicals was explicitly shown by the ability of ketenimine to initiate polymerization of styrene. The efficiency of radical production from ketenimine is less than the AIBN efficiency. This implies that the solvent cage is looser in the AIBN decomposition.

Rate constants for formation and decomposition of this ketenimine in the presence and absence of scavengers provide the basis for the hypothesis that the product ratio from the AIBN-produced cage favors ketenimine, while the product ratio from the ketenimine-produced cage favors TMSN.

Formation of ketenimine in a loose AIBN cage may be explained by one of two paths. (1) Ketenimine may be produced by a nonradical decomposition of AIBN, or (2) AIBN may produce an azo radical and a 2-cyano-2-propyl radical on decomposition. These radicals would be expected to preferentially produce the ketenimine for steric reasons.

¹Doctoral thesis number 1907, submitted May 3, 1957.

Chairman of Committee, George S. Hammond, Department of Chemistry.

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ELECTRONIC SPECIFIC HEAT OF SODIUM TUNGSTEN BRONZE¹Robert Wilson Vest²

Department of Chemistry

The design and operation of a calorimeter for use in the temperature range 1.8-4.2°K are presented, and the methods used in the treatment of data and calculation of results are discussed.

The heat capacities of several sodium tungsten bronzes (Na_xWO_3) were determined in the temperature interval 1.8-4.2°K. Samples having x equal to 0.89, 0.81, 0.73, 0.65, and 0.56 were studied. The measured heat capacities are described adequately by the sum of two terms, one linear and one cubic in temperature. The electronic specific heat of each sample is obtained by evaluating the coefficient of the linear term, and the Debye characteristic temperature derived from the coefficient of the cubic term.

Densities of one-electron energy levels at the Fermi energy, and effective electronic masses are calculated from the electronic specific heats. A plot of the density of states as a function of energy can be made if it is assumed that this curve is independent of sodium concentration. The justification of this assumption is discussed in the light of current theories of the solid state. The density of states curve rises rapidly at higher energies, and this rise is interpreted in terms of the filling of a Brillouin zone or of an overlap of two bands.

¹Doctoral thesis number 1886, submitted March 6, 1957.

Chairman of Committee, Harley R. Wilhelm, Department of Chemistry.

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Research Assistant, Institute for Atomic Research.

USE OF SOME COMPLEXES OF IRON, CERIUM, AND
N-METHYL-3,5-DIBROMOSALICYLALDIMINE IN
ANALYTICAL CHEMISTRY¹Earl Preston Wadsworth, Jr.²

Department of Chemistry

Use was made of the strong complexes formed between iron(III) and phosphate to develop an improved method of solution for iron ores which is applicable to those analyses in which the amalgamated zinc reductor is used. The undesirable properties of phosphoric acid as a solvent were overcome by using an equivolume mixture of 85 per cent phosphoric and 72 per cent perchloric acids as the ore solvent. Seventy-two per cent perchloric acid, 85 per cent phosphoric acid, and mixtures containing 75 volume per cent of each of the acids were not as satisfactory as the equivolume mixture. The solvent mixture used satisfactorily dehydrated any silica present, did a more thorough job of removing iron from the silica present than hydrochloric acid, gave solutions satisfactory for reduction by the amalgamated zinc reductor, and dissolved those samples which were tested within 10 minutes. Analyses were

¹Doctoral theses number 1821, submitted July 11, 1956.

Chairman of Committee, Charles A. Goetz, Department of Chemistry.

²B.S., University of New Hampshire, Durham. M.S., *ibid*.

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carried out on electrolytic iron, the National Bureau of Standards standard iron in iron ore sample (no. 27), and a number of Standard Sample Company samples (Hach Chemical Company, Ames, Iowa). Satisfactory results were obtained.

The potential of the cerium(III)-cerium(IV) half-cell was considered in some detail with an attempt being made to locate a standard oxidation potential which was consistent with experimental data available in the literature. Calculations based on the sulfate and perchlorate systems yielded standard potentials of -1.79 and -1.75 volts, respectively. The agreement may be considered as being good when the uncertainty in the constants for the various hydrolyzed (perchloric acid solutions) and complex species (sulfuric acid solutions) present is considered; the fact that the observed experimental potentials for sulfuric acid solutions of the couple vary from -1.44 to -1.42 volts, whereas those for perchloric acid solutions vary from approximately -1.70 volts to -1.87 volts makes the above agreement even more satisfactory. Only qualitative success was obtained in the case of nitrate and chloride solutions of the couple.

Recent years have witnessed a number of papers dealing with the rate of electron exchange between the cerium(III) and cerium(IV) species in solutions containing nitric and perchloric acids. The results show that the exchange is measurably slow and that it is not appreciably catalyzed by bright platinum or platinized platinum. Such investigations have introduced serious doubts as to the thermodynamic reversibility of the cerium(III)-cerium(IV) couple. The spontaneous decomposition of cerium(IV) solutions containing perchloric, nitric, and hydrochloric acids makes the rate of the exchange reaction especially important. The rate of exchange must be very fast with respect to any spontaneous cell reactions if the cell is to be a reversible one.

Evidence was presented which would place the standard oxidation potential of the cerium(III)-cerium(IV) couple at approximately -1.75 volts if the criteria of thermodynamic reversibility are satisfied.

The use of N-methyl-3, 5-dibromosalicylaldehyde as an analytical precipitating agent was investigated in both alkaline aqueous media and slightly acidic acetone-water mixtures. The use of alkaline media was found to be extremely unsatisfactory in that selectivity, nature of the precipitate, and coprecipitation of the reagent produced serious errors which could not be practically overcome. The use of slightly acidic acetone-water mixtures, although not completely satisfactory, did indicate promise for the use of the reagent for semimicro quantities of copper(II) provided that copper constituted a major constituent of the material being analyzed. Nickel(II), iron(II), and mercury(II) were also precipitated from weakly acidic acetone-water mixtures, but under such conditions that the presence of most transition metal impurities could not be tolerated.

The nature of the precipitate (amorphous) as to filterability was poor in both alkaline aqueous and weakly acidic acetone-water solutions with the exception of the mercury(II) precipitate (crystalline). Precipitates weighing much more than 0.1 gram required impractical lengths of time for filtration. In all of those cases studied the precipitate contained two reagent molecules for each metal ion.

The precipitates had the undesirable properties of poor filterability, and large coprecipitation errors. Desirable properties of the reagent included the extremely favorable gravimetric factors obtainable and the high relative selectivity possible in mixed organic-water solvents.

FUNGICIDAL EFFECT OF TRIETHYLENE GLYCOL VAPOR
ON SPORES OF *PENICILLIUM NOTATUM*¹Charles Bradley Ward, Jr.²

Department of Dairy and Food Technology

It was the purpose of this study to determine the extent of effectiveness of triethylene glycol (TEG) vapor upon spores of *Penicillium notatum* under various conditions. Also investigated were various aspects regarding the mechanism of action of TEG vapor.

A static type of observation (noncontinuous air-flow) was used in conducting studies in an experimental chamber, and air samples were taken using sieve air-samplers (duBuy and Crisp, 1944) and settling plates simultaneously. TEG vaporization was by means of a commercial vaporizer (Glycoaire), allowing a maximum temperature of 200°F applied momentarily to the TEG. The average particle size of the spores atomized from aqueous suspension throughout these studies was calculated to be 3.9 microns by use of Stokes' Law.

Collection of spores, vapor treated and nonvapor treated, from the air and microscopic examination of them after various incubation periods indicated that about 87 per cent of air-borne spores of *P. notatum* exposed to TEG vapor for a period of 8 minutes did not germinate after 14 hours. Upon incubation of spores exposed for 23 minutes, it was found that in most cases 100 per cent of the spores failed to germinate after 5 days. It was concluded that spores of *P. notatum* were not merely settled by TEG, but that a killing effect was evident.

Results of TEG vapor concentration studies indicated that at the relative humidities employed (about 50 per cent) the vapors of TEG were essentially ineffective against spores of *P. notatum* until approximately 2/3 saturation was reached. At about 3/4 saturation the vapor was as effective as at near-saturation or at supersaturation. This is contrary to the findings of Mellody and Bigg (1946) who reported that a TEG concentration of 10 to 35 micrograms per liter of air was necessary to produce rapid and complete killing. These concentrations are those of supersaturated atmospheres (Wise and Puck, 1947) at normal room temperatures.

On testing relative humidities ranging from 15 to 90 per cent, the effective range of action for TEG vapors against the spores was found to be 35 to 60 per cent with a rapid drop in action outside this range. Viable *P. notatum* spores disappeared from the air at a rate equivalent to about 16 air-changes per hour in the effective range of relative humidity.

The effect of temperature was investigated only very briefly. A portion of a spore suspension was exposed to an atmosphere of supersaturated TEG vapor at 83°F and another portion to a similar atmosphere at 105°F. The killing rate at the higher temperature was more than double that at the lower. It should be mentioned, however, that the increased killing rate at the higher temperature could have resulted, in part, from the increased vulnerability of the spores because of incipient germination (4 hr in distilled water) prior to atomization. With the equipment used, temperature could not be controlled well. However, within the temperature range of the other data in this study (76 to 85°F) the confounding effect of temperature difference is thought not to be serious, since some of the highest temperatures occurred in tests in which practically no killing resulted. In addition, results of similar experiments were averaged to reduce the effect of temperature variation.

¹ Doctoral thesis number 1824, submitted July 11, 1956.

Chairman of Committee, R.S. Allen, Department of Animal Husbandry.

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Spore particles of P. notatum (mean diameter about 5.4 microns), blown from an agar slant culture by means of air, were found to be killed by TEG vapor. However, they proved more resistant (removed at rate equivalent to about 12 air-changes per hour) than spores atomized from aqueous suspension.

Grün (1950) has reported formaldehyde as a component of TEG vapors, and has suggested it might be responsible for the bactericidal action of TEG. In the present study, while investigating the possibility that degradation products of TEG could be the effective fungicidal agents in TEG vapors, it was found that formaldehyde was present in TEG (Air Treatment Grade), in vapors of TEG taken from an experimental chamber, in vapors arising when TEG was heated in a boiling water bath while bubbling air through it, and in the residual TEG after vacuum distillation of a portion of the TEG.

The existence of glyoxal (probably derived from glycolaldehyde because of the analytical method used) in TEG vapors or the liquid, even after distilling off half of the material under vacuum, was demonstrated by the absorption and chromatographic behavior of its 2,4-dinitrophenylhydrazone. Other probable dissociation products of TEG or possible products of further air oxidation were observed on paper chromatograms but were not identified. These products consisted of both mono- and dicarbonyl compounds (about 4 in all).

Several compounds which were postulated early in this study as possible degradation products of TEG (i.e., glycolaldehyde, glycolic acid, glyoxal, and glyoxylic acid) were tested as vapors (present in quantities to produce a visible fog) against spores of P. notatum. It was found that glycolaldehyde and glycolic acid were five to six times as effective air disinfectants as TEG. Glyoxylic acid was found to be twice as effective, while glyoxal appeared to be of the same order of effectiveness.

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ECOLOGICAL STUDIES OF EUROPEAN CORN BORER POPULATIONS
IN BOONE COUNTY, IOWA¹Gerald Thomas Weekman²

Department of Zoology and Entomology

The purposes of this investigation have been to record the seasonal and annual populations of the European corn borer (*Pyrausta nubilalis* (Hbn.)) as they occur in Boone County, Iowa and to evaluate the various environmental conditions that influenced the borer populations in that area from 1954 through 1956.

Within the corporate boundaries of Boone County, 32 fields were selected randomly, two from each of 16 equal areas. In each field 20 plants were selected in two sites and marked for twice-weekly observations of the following: corn borer oviposition, fate of all eggs deposited, the extended height of the corn plants, and the predators present on each plant. In addition the corn plant residue in three, 1/2000 acre samples taken at random in each field was examined to determine corn borer larval populations and survival at selected periods during each year.

Observations of the seasonal development of the borer were also made during the growing season of each year to determine the value of temperature accumulation (degree days) as a method by which to predict the occurrence of the various stages in the life cycle.

The percentage of parasitism in the overwintering corn borer larvae in Boone County was determined by rearing larvae that were collected during the fall population observations.

As a result of these observations it was determined that average egg populations during the spring oviposition period reached 162 egg masses per 100 plants in 1954, 37 egg masses per 100 plants in 1955, and 46 egg masses per 100 plants in 1956.

Summer egg populations for the three seasons were: 642 egg masses per 100 plants in 1954, 65 egg masses per 100 plants in 1955, and 42 egg masses per 100 plants in 1956.

The computed survival of eggs deposited for each season was: in 1954, 9.1 per cent of the spring oviposition, and 4.5 per cent of the summer oviposition. In 1955, 7.6 per cent of the spring oviposition and 11.5 per cent of the summer oviposition. Results in 1956 showed that 6.1 per cent of the spring oviposition and 18.3 per cent of the summer oviposition survived.

The rate of plant growth as computed was 1.8 inches per day in 1954, 1.4 inches per day in 1955, and 1.6 inches per day in 1956.

Predator populations averaged 0.9 predator per plant during spring oviposition and 6.1 predators per plant during summer oviposition in 1954. In 1955 predator populations averaged 0.9 predator per plant and 6.4 predators per plant during spring and summer oviposition, respectively. The 1956 predator populations per plant were 1.4 predators at spring oviposition and 22.2 predators for summer oviposition.

Spring populations observed in 32 fields planted to corn the previous year showed an average of 6,240, 12,000, and 840 live borers per acre for the 1954, 1955, and 1956 seasons, respectively.

Midseason populations of the borer as estimated on the average were: 223 larvae per 100 plants in 1954, 44 larvae per 100 plants in 1955, and 43 larvae per 100 plants in 1956.

¹Doctoral thesis number 1913, submitted May 28, 1957. Chairman of Committee, Tom A. Brindley, Department of Zoology and Entomology.

²B.S., Gustavus Adolphus College, St. Peter, Minnesota. M.S., Iowa State College, Ames. Graduate Assistant, Agricultural Experiment Station.

Fall populations averaged 565 living larvae per 100 plants in 1954, 151 larvae per 100 plants in 1955, and 188 larvae per 100 plants in 1956.

Winter mortality as determined by comparison of the fall and spring populations of live corn borer larvae gave estimates of 80.8 per cent in 1954-54, 84.4 per cent in 1965-55, and 95.6 per cent in 1955-56 seasons.

Spring development as recorded for the three seasons was: first pupation occurred May 14 in 1954, April 29 in 1955, and May 21 in 1956. First emergence of moths was observed May 31 in 1954, May 17 in 1955, and June 7 in 1956; first oviposition was recorded June 14 in 1954, June 3 in 1955, and June 8 in 1956.

Summer pupation reached the rate of 80 per cent of midseason populations in 1954, 83 per cent in 1955, and 8 per cent in 1956.

The percentages of parasitism were: 15.9 per cent in 1954, and 16.2 per cent in 1955.

From the results given for the 1954, 1955, and 1956 seasons and an evaluation of data from the 1950 through 1953 seasons the following generalizations seem valid:

1. Cool wet springs such as experienced in 1950 and 1951 limit the corn borer population largely to a single oviposition period. That period occurs during June and early July.

2. Hot dry periods which occur after the completion of spring oviposition as in 1956 will not adversely affect corn borer survival and subsequent corn borer populations.

3. Accurate estimates of the occurrence of the various stages in the corn borer life cycle can be obtained by use of temperature accumulation based on a developmental threshold of 50°F.

4. Spring corn borer oviposition is positively correlated with the extended height of the corn plants at mid-oviposition as well as the rate of corn plant growth.

5. Sampling techniques in which 20 plants are selected in two sites in each field gave adequate estimates of corn borer populations in those fields.

PURIFICATION OF THORIUM BY SOLVENT EXTRACTION¹

Marvin E. Whatley²

Department of Chemical Engineering

Investigations were made of the solvent extraction of thorium nitrate with tributyl phosphate from aqueous solutions containing phosphate, sulfate, and nitric acid. It was the specific objective to develop a process to produce pure thorium from a thorium concentrate obtained by the selective precipitation of thorium phosphate from a monazite-sulfuric acid solution.

A study of the effect of a diluent in the solvent mixture led to the choice of 80 per cent tributyl phosphate--20 per cent inert diluent. The effects of phosphate, sulfate, and nitric acid on the thorium distribution coefficient were studied in detail. The thorium distribution coefficient was greatly decreased by the presence of phosphate, decreased to a lesser extent by the presence of sulfate, and greatly increased by the presence of large amounts

¹Doctoral thesis number 1440, submitted July 13, 1953. Chairman of Committee, Morton Smutz, Department of Chemical Engineering.

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of nitric acid. It was found that, by the use of high concentrations of nitric acid, the detrimental effect of phosphate and sulfate could be overcome and thorium extracted from solutions containing up to 20 grams per liter phosphate (P_2O_5) and/or sulfate.

Because the use of 80 per cent tributyl phosphate afforded only a small difference in density between the solvent and aqueous phases, it was necessary to develop a mixer-settler with exceptionally good interface level control. The principle of operation and the design of both a laboratory glass unit and a box-type unit adaptable to industrial use are discussed.

A pilot plant extractor was assembled and a continuous counter-current extraction run was made. The capacity of the unit was 0.39 pounds of thorium per hour. The feed, containing about equal parts thorium and rare earths, was prepared from a thorium phosphate concentrate from the Ames monazite process. There were seven stages in the extraction section, nine stages in the scrub section, and five stages in the strip section. The recovery of thorium was 92 per cent and the product thorium contained less than four parts per million total rare earths. The selection of operating conditions for the run and the interpretation of the data are discussed.

A preliminary cost estimate was made of a process to purify thorium from the thorium concentrate from the Ames monazite process. The total conversion cost for a production rate of five tons of thorium per month was about \$2.07 per pound of thorium.

NATURE AND EFFECTS OF RESIDUAL SOIL NITROGEN¹

William Calvin White²

Department of Agronomy

Field observations and experimental data have shown that nitrogen applied to corn in Iowa has increased yields of succeeding oat and corn crops. As is the case with any residual nutrient, the most important problems of utilizing residual nitrogen concern determining its quantities and forms in soil. The objectives of this study were to estimate the quantities of residual nitrogen resulting from fertilizer applied to corn and to determine its nature, namely, its form and location in soil.

This study included investigations in the field, laboratory, and greenhouse. Field experiments were employed to measure effects of nitrogen applied to corn on the nitrogen content of soils to depths of at least 21 in. in the season applied and in the following season. They also served to measure effects from nitrogen applied to corn on grain, dry matter, and nitrogen yields of the succeeding oat crop. Carry-over of nitrogen was studied in soils of the Carrington, Webster, Cresco, Galva, Ida, Monona, Nicollet, Marshall, Sharpsburg, and Edina series. In a greenhouse experiment, nitrogen enriched with N^{15} was applied to a Carrington silt loam having varying quantities of residual nitrogen in each of three depths resulting from nitrogen applied the previous year to corn.

Procedures for estimating quantities of residual nitrogen under field and greenhouse conditions involved determining the rate of increase of nitrogen in oat plants with rates applied directly in the residual year. From this

¹Doctoral thesis number 1889, submitted March 11, 1957.

Chairman of Committee, John Pesek, Department of Agronomy.

²B.S., Virginia Polytechnic Institute, Blacksburg. M.S., Iowa State College, Ames. Graduate Assistant, Agricultural Experiment Station.

information, expressed as the regression of nitrogen yield on nitrogen added directly, an increase in nitrogen yield over that obtained at the zero-residual level was expressed as a quantity of the directly applied nitrogen. Thus, the estimated residual quantities were evaluated in units of the nitrogen applied directly.

There were three forms in which residual soil nitrogen was considered possible to occur. They were nitrifiable nitrogen in organic forms, ammonium, and nitrate nitrogen. Consequently, nitrification rate tests were made for the first of these forms and chemical analyses of soil for the last two. Due to the fact that location of nitrates in soil is conditioned by movement of water through soil, the above three possible forms of residual nitrogen were studied in each of three soil depths, 0 to 6, 6 to 12, and 12 to 21 in.

The largest measured oat grain yield increase resulting from residual nitrogen was 29 bu per acre on a Galva silt loam. This grain yield increase was obtained in 1953 where 180 lbs of nitrogen per acre were applied to corn in 1952. Effects of residual nitrogen from initial applications as small as 40 lbs per acre were not generally statistically significant in experiments of this study.

Methods using the linear regression of nitrogen yield of oats on nitrogen added directly in the residual year were applied successfully in estimating quantities of residual nitrogen in soil. Difficulties arising from interactions between levels of residual and directly applied nitrogen were pointed out and alternative procedures were employed using the regression data.

Quantities of residual nitrogen estimated by means of the nitrogen yield regressions tended to increase as the initial rates of applications increased. The largest estimated quantity of residual nitrogen was 88 lbs per acre resulting from the 180-lb application in 1952 on the Galva silt loam mentioned above. This residual quantity was equivalent in effect to 49 per cent of the initial application.

Under conditions of the experiments, residual nitrogen resulting from applications of chemical fertilizers appeared to be in the form of nitrates. No appreciable quantities of residual ammonium nitrogen could be found at the end of the corn season in which ammonium nitrate was applied, not in the following spring. Nitrification rates of soil one year after the initial applications also appeared to be unaffected by the initial fertilizer applications.

An important characteristic of residual nitrogen found in this study was its location. With the exception of an Edina soil sampled in 1956, all soils in which significant quantities of residual nitrogen were found contained most of the residual nitrates in the 6 to 21-in. depth. In most of the soils studied, quantities of residual nitrates increased in order with the depths, 0 to 6, 6 to 12, and 12 to 21 in. These results point out the inadequacy of samples taken from only the plow layer for providing estimates of residual nitrogen.

Approximately 66 per cent of the quantities of residual nitrogen estimated by means of the nitrogen yield regressions could be accounted for by the residual quantities of nitrate nitrogen found in soil to a depth of 21 in. before growth of the oat crop. On the basis of the reported soil profile distribution of nitrates, there is reason to believe that analyses of soil at a greater depth would have shown a larger quantity of residual nitrogen as nitrates.

Multiple regression analyses, where nitrogen yields of oats were related to nitrate nitrogen in the above three soil depths, and simple linear regressions with single depths showed a high correlation between effects of residual nitrogen on plants with those measured by soil nitrate analyses. Nitrogen yields of oats were more highly and more frequently correlated with residual nitrates in the 6 to 12 and 12 to 21-inch depths than in the plow layer. Nevertheless, coefficients of regressions of nitrogen yield on soil nitrate nitrogen in the 0 to 6-inch depth were greater than 2.0 in several experiments where large quantities of residual nitrates were below the surface depth. Thus, it appeared that quantities of nitrate nitrogen in the surface depth, even though they were small in comparison to those in other depths, resulted in increased

growth of roots that in turn enabled plants to utilize the residual nitrates better in the sub-soil. The same reasoning appears feasible for observed positive interactions between levels of residual and directly applied nitrogen on plant yields.

Employment of isotopic nitrogen in the greenhouse experiment provided more positive evidence of the cause-and-effect relationship between residual soil nitrates and residual effects on plant yields than was possible to obtain from total nitrogen yield data. It allowed expressing the total nitrogen content of the harvested oat plants as a sum of nitrogen derived from that added directly, from soil nitrogen other than initial nitrates, and from initial soil nitrates. Increased nitrogen yields of oats, resulting from applications made a previous year to corn in the field, were largely due to quantities of residual nitrates in the 12 to 21-inch depth of the soil used.

ELECTRICAL RESISTIVITY OF THIN FILMS OF POTASSIUM¹

David Gilbert Worden²

Department of Physics

The electrical resistivity of thin potassium films at 100°K has been measured as a function of thickness in the thickness range 148 to 1600 angstroms. The experimental results are in excellent agreement with Fuchs' theoretical predictions in the range 500 to 1600 angstroms and show that the scattering of the electrons at the film surfaces is completely diffuse. Comparison of experimental and theoretical curves gives a bulk resistivity parameter of 1.85 microhm cm, a mean free path of 1180 angstroms, and an electron to atom density ratio of 1.01. The films were deposited on a pyrex substrate from a beam of potassium vapor in a vacuum chamber which had a pressure less than 5×10^{-8} mm of Hg. The film thickness, in each case, was computed from a known beam intensity, exposure time, and film density. A surface ionization detector was used to calibrate the beam intensity (J_1) as a function of effusion oven temperature (T_0). The linear plot of $\log (J_1 T_0^{1/2})$ versus T_0^{-1} gave a heat of sublimation for potassium at 450°K of 21.1 kcal/mole in good agreement with Brewer's value of 21.4 kcal/mole within our experimental error.

¹Doctoral thesis number 1837, submitted August 10, 1956.

Chairman of Committee, G. C. Danielson, Department of Physics.

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APPLICATION OF THE ROLLER-CRUSHER PRINCIPLE
TO PROCESSING CORNCOB¹Roger Raymond Yoerger²Departments of Agricultural Engineering and of
Theoretical and Applied Mechanics

The development of the Ames Cob Crusher offers a partial solution to the economical utilization of large quantities of corncobs on the farm where they are produced. This machine utilizes a roller-crusher mechanism to compress the corncobs laterally thereby causing them to break into longitudinal quarter sections. The quartered pieces are then passed through a sizing unit consisting of a toothed cylinder and concave arrangement for breaking the quarters into short lengths suitable for bedding and litter.

A study was conducted to determine the relationship between the performance of the roller-crusher mechanism, the design of the mechanism and physical properties of the corncobs. The design variables of the mechanism included crushing roll diameters, roll lengths, roll spacing, feeder bar spacing, roll speed, and speed ratio between the two individual rolls. The variable properties of the corncobs included corncob diameter, apparent wet specific weight and unit energy of compression required to accomplish quartering.

The method of dimensional analysis was used in setting up the test procedure. The application of the Buckingham Pi Theorem made it possible to reduce the number of arguments from the twelve variables involving the basic dimensions of force, length, and time to nine independent and dimensionless groups (Pi terms). An expression for the performance of the roller-crusher mechanism was then set up in terms of a function involving the nine Pi terms. The form of the function was determined by a laboratory test procedure where all Pi terms, except two representing the independent and dependent variables were held at a constant value. This procedure was carried out for each Pi term serving in turn as the independent variable.

A roller-crusher test stand was constructed and instrumented to facilitate carrying out the test procedure to obtain a component equation for each of the individual Pi terms. The component equations were combined to produce the final prediction equation for the performance of the roller-crusher mechanism. The variables were all found to be separable and the general prediction equation was formed by multiplication of the exponential component equations.

The general prediction equation can be used to predict the performance of the roller-crusher mechanism for any combination of variables within the ranges considered in the study. The spacing between the roll surfaces was the most important factor influencing the energy requirement for quartering corncobs with the roller-crusher mechanism. The energy requirement for crushing corncobs 1.04 inches in diameter was increased by 127 per cent as the roll spacing was decreased from 11/16 inch to 1/2 inch. The performance of the 8.62, 10.75, and 12.75 inch diameter crushing rolls was nearly equal from the standpoints of maximum capacity and energy requirement. Operating the crushing rolls at differential speeds resulted in a sizeable increase in energy requirement and a decrease in capacity. The energy requirement was also increased as the number of feeding bars on the crushing rolls was increased.

A second phase of the investigation was to evaluate the merit of the two

¹Doctoral thesis number 1914, submitted May 29, 1957. Chairmen of Committee, Kenneth K. Barnes, Department of Agricultural Engineering, and Glenn Murphy, Department of Theoretical and Applied Mechanics.

²B.S., Iowa State College, Ames. M.S., *ibid.*
Assistant Professor, Agricultural Engineering.

stage reduction system for corncobs utilizing the roller-crusher mechanism to quarter the corncobs and a conventional farm grinder or the sizing unit from the Ames Cob Crusher for the final reduction. The performance of the various reduction processes were compared on the basis of total unit energy requirement, capacity, and fineness of product. A vertical burr grinder, horizontal burr grinder, and a hammermill, all typical of machines found on farms, were instrumented to determine the power required for grinding.

Tests were conducted with each of the farm grinders listed above with whole corncobs containing 13.87 per cent moisture and compared with similar tests in which the corncobs were passed through the roller-crusher unit before final reduction. The performance of the vertical burr mill was improved by pre-crushing the corncobs with an increase in capacity up to 22.3 per cent and a reduction in total energy required by as much as 24.3 per cent. Pre-crushing the corncobs before final reduction showed less improvement with the horizontal burr mill. This may be partially attributed to the rotating cob cutter and stationary concave arrangement used on this machine for feeding material to the burrs. The hammermill required more energy and had a lower capacity for processing the pre-crushed corncobs than for whole corncobs reduced to the same mean weight diameter. For a given screen size the product particle sizes were smaller when processing whole corncobs than those that had been pre-crushed.

Processing pre-crushed corncobs with the sizing unit produced a coarser product suitable for animal bedding and litter. The energy required by the unit was a minimum at about 375 revolutions per minute and as the speed was increased the energy requirement increased and the particle size decreased. The total energy requirement for processing corncobs with the roller-crusher and sizing unit was 1.78 horsepower-hours per ton.

The use of a roller-crusher mechanism for quartering corncobs prior to final reduction by a farm size burr grinder improved the performance from the standpoint of capacity and energy requirement. Pre-crushing did not improve the performance of the farm size hammermill.

DETERMINATION OF STREAMLINES USING A PHOTOVISCOUS FLUID¹

Donald Fredrick Young²

Department of Theoretical and Applied Mechanics

The object of the investigation is to determine the feasibility of using a photoviscous fluid for the quantitative prediction of general two-dimensional flow patterns around submerged bodies and to determine the required techniques. The emphasis is placed on the solution of fluid mechanics problems from a phenomenological viewpoint and no attempt is made to explain the underlying reasons for the double refraction.

The fluid used in the investigation is a solution of milling yellow dye and distilled water. Isoclinic and isochromatic patterns for two-dimensional flow around a circular cylinder, a half-body, and for parallel flow are obtained for several milling-yellow solutions at various rates of flow. For all tests the velocities are low so that inertia forces can be neglected. The geometry of

¹Doctoral thesis number 1867, submitted December 12, 1956. Chairman of Committee, Glenn Murphy, Department of Theoretical and Applied Mechanics.

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Assistant Professor.

the experimental apparatus is such that approximate solutions to the Newtonian equations describing the flow are known. An attempt is made to relate the optical patterns to various flow parameters, but no satisfactory correlation is obtained. For areas in the fluid field where the directions of the principal stresses can be evaluated without recourse to the Newtonian relationships it is found that the optic axes in the fluid coincide with the principal stress directions.

The existence of normal stresses, which cannot be accounted for from Newtonian theory, is proposed and experimental evidence is presented to support this idea. The magnitude of the apparent normal stress rate is calculated and related to the apparent rate of strain. In general the experimental data indicate that the behavior of the milling yellow solution is non-Newtonian.

A method is proposed for predicting the streamlines of two-dimensional flow around submerged bodies. In order to develop a satisfactory technique it is assumed that the optic axis in the fluid coincides with the principal stress directions and the magnitude of the maximum shearing stress is related to the retardation of the component light rays as they pass through the fluid. The proposed technique is not restricted to Newtonian fluids. The type of calibration data which is required for prediction is indicated and a suitable experimental set-up is described. The method to be used in obtaining the streamlines from the experimental data is outlined.

EFFECT OF PEREZIA PYRAUSTAE PAILLOT ON THE
EUROPEAN CORN BORER, PYRAUSTA NUBILALIS (HÜBNER)¹

Harold Lincoln Zimmack²

Department of Zoology and Entomology

Early in 1952 two-fold difficulties were encountered in the European Corn Borer Research Laboratory, Ankeny, Iowa, when hibernating larvae of the European corn borer, *Pyrausta nubilalis* (Hübner), were incubated to provide eggs for laboratory insecticide tests. Larval mortality was high and emerged moths failed to lay a normal number of eggs. Dead larvae were submitted to Dr. E.A. Steinhaus, Head of the Division of Biological Control, University of California, Berkeley. Dr. Steinhaus identified several pathogens, among them an intracellular protozoan parasite, *Perezia pyraustae* Paillot (Sporozoa, Microsporidia, Nosematidae).

To determine the effect of the parasite upon the corn borer, the study was divided into three parts: (1) rearing experiments using synthetic food medium to rear infected and noninfected corn borers through one complete generation; (2) a study of egg production and longevity of infected and noninfected mated female moths; (3) histological studies of infected and noninfected corn borers in various stages of development to determine the systems infected and the extent and degree of infection.

The synthetic medium employed in larval rearing experiments was a bacto-agar carrier to which adequate nutritive constituents had been added. The medium was stable and did not require renewal during larval development. An aseptic technique was employed to minimize contamination of the medium.

¹Doctoral thesis number 1830, submitted July 23, 1956.

Chairman of Committee, Tom A. Brindley, Department of Zoology and Entomology.

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Copulating moths were captured in a large outdoor cage at the Ankeny Experiment Station. The cage contained corn borer-infested stalks from Polk County, Iowa. Each captured pair was placed in individual oviposition chambers and data on egg production and longevity were recorded.

Histological sections on all stages of diseased corn borers were prepared and analyzed. All corn borers that were prepared for histological evaluations were reared on the synthetic medium and were obtained from egg masses laid by infected females. Some of these eggs were naturally infected and some were not infected.

A total of 360 hatched first instar larvae were reared on uncontaminated synthetic food medium. In the diseased group 56 per cent developed into adults as compared with 77 per cent of the uninfected group. Dead corn borers were dissected and examined microscopically to determine whether or not P. pyraustae was present. Emerged male and female moths were paired and fecundity and longevity data were recorded. Infected moths averaged three days shorter life and produced an average of 39 less eggs than uninfected moths. Although mortality was 21 per cent higher in the diseased group, the rearing experiments showed that as in field conditions, larvae infected with P. pyraustae can develop into moths that can mate and produce fertile eggs.

Fecundity and longevity data on copulating moths collected at the Ankeny Experiment Station showed that the Perezia-infected moths compared with the uninfected moths averaged three days shorter life, nine fewer egg masses and laid 47 per cent fewer eggs.

Histological evidence of transovarial transmission of the parasite was demonstrated in the ovary of the corn borer. P. pyraustae spores were shown passing from the region of infected nurse cells into the developing oocyte. Diseased males did not play any part in the transmission of the disease through copulation with uninfected females.

The Malpighian tubules were the chief site of infection in the host. Usually infection in these organs was absent or light during the first and second instar stages but increased rapidly in subsequent development. The digestive tract was infected in more than half of the infected specimens. The cellular elements of the nervous system were infected in the majority of the corn borers. Silk glands were often infected. The reproductive system was infected in more than one-third of the moths. The following structures in the European corn borer, for the first time, have been recorded parasitized infrequently by P. pyraustae: the integument, muscles, fat body, and salivary glands.

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- TRAFTON, CLARK WRIGHT
An extension of Hensell's lemma to topological modules. Mathematics.
- TUN, KYI
Burmese rice price policy. Economics and Sociology.
- VOLAND, MAURICE EARL
Factors related to participation in an extension program. Economics and Sociology.
- VON KROSIGK, CARL MAX
Effect of inbreeding on production in Holsteins. Animal Husbandry.
- VORIS, JOHN CALVIN
Factors influencing the summer roadside count of the cottontail rabbit (*Sylvilagus floridanus mearnsi*) in south-central Iowa. Zoology and Entomology.
- WALLACE, DUANE CONRAD
Specific heat of high purity iron by a pulse heating method. Physics.
- WELCH, DEANE ELLIOTT
Effect of fly ash on strength of Portland cement stabilized soils. Agronomy.
- WESCOAT, WENDELL MAYNARD
Attitudes of farm-reared male graduates of the Ogden High School toward agricultural programs. Vocational Education.
- WHADE, ENID ELAINE
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- WHITEFORD, ROBERT DANIEL
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- WICKSTROM, ALDEN EUGENE
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- WILLIAMS, TESS MERN
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WILLIAMS, WILLIAM HOWARD

Post stratification estimates for multistage samples. Statistics.

WILLSIE, ROGER H.

Compensation as a means for obtaining improvements on rented land in western Iowa. Economics and Sociology.

WILSON, JOHN

Relations between the daughter average and the average of their dams in the proof of Holstein-Friesian sires. Animal Husbandry.

WOHLAUER, GABRIELE ELISABETH

The structure of palladium dimethylglyoxime. Chemistry.

WOLFE, HAROLD EUGENE

Flow of an aqueous slurry through a vertical tube. Theoretical and Applied Mechanics.

WOLFE, WILLIAM BARTOW

Gamma ray scattering within thin-walled shells. Engineering.

YAO, YI MING

Estimation of evaporation from water surfaces in Iowa. Agronomy.

Degree Master of Landscape Architecture

KAWAMOTO, MITSUO

Some factors influencing the location of the Mississippi River Parkway and parkways in Iowa.

KREISER, HAROLD ROY

Landscape architectural design of the cemetery.

PUBLICATIONS OF MEMBERS OF THE STAFF
OF THE IOWA STATE COLLEGE FOR
THE ACADEMIC YEAR 1956-57

Certain summaries and indices are of interest in a survey of the publications of members of the staff of an educational and research institution such as the Iowa State College. The publications are listed in alphabetic order under the names of the senior authors. Junior authors are also listed alphabetically with cross reference to senior author.

SUMMARY

Number of individuals listed.	780
Number of publications.	769
Number of publications with single author	301
Number of publications with joint authorship.	468
Number of departments or fields represented in publications	46
Number of individuals who serve as editors or on the editorial staff of one or more scientific or technical periodicals.	43

Individuals thus serving are: Atkins, Ayres, Baker, M.P., Bear, Becker, Biester, Black, Bolton, Brown, F.E., Buchapan, Carlander, Davis, Diehl, Dwelle, Errington, Fassel, Fox, F.A., Getty, Gowen, Hammond, Heady, Heer, Hurley, Johnson, I.J., Kempthorne, Kenkel, Kirkham, Kuetemeyer, Kutish, Lockhart, Pesek, Pierre, Royer, Snedecor, Sprague, Sullivan, Swanson, Swenson, C.A., Swenson, M.J., Tintner, Van Horn, Weber, Werkman.

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